Final Report

Evaluating Biomass Energy Opportunities for the Colorado Front Range

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Finally, despite our best efforts at editing and revisions, mistakes may still remain within this document. Any mistakes or omissions are the sole responsibility of the authors. Any questions or comments should be addressed to McNeil Technologies Inc., 143 Union Blvd, Suite 900, Lakewood, CO 80228. McNeil staff that worked on this project included Randy Hunsberger, Scott Haase, and Tim Rooney.

DISCLAIMER

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°F.....................degrees Fahrenheit
$.......................U.S. dollars
bdt……………Bone dry tons
Btu...................British thermal unit
Btuh.................Btu/hour
C&D…………Construction and Demolition waste
CSFS .....……Colorado State Forest Service
CDPHE ....Colorado Department of Public Health and the Environment
cf ....cubic feet (ft^3)
dbh……………diameter breast height
DOE…………United States Department of Energy
EPA.................Environmental Protection Agency
ft......................feet
gal....................gallon
GT ....green tons
kW...................kilowatt
kWe………… kilowatt electric
kWth…………kilowatt thermal
kWh.................kilowatt-hour
MMBF……….million board feet
MMBtu............million British thermal units
MMBtuh..........MMBtu per hour
MW.................megawatt
MWh...............megawatt-hour
MWth………..megawatt thermal
NO_x…………..Oxides of nitrogen
OEMC.............Colorado Governor's Office of Energy Management and Conservation
PM10…………Particulate matter of 10 microns in size, or smaller
QF……………Qualifying Facility
UTR…………..urban tree residue
TPSQ…………timber product supply quantity
USA................United States of America
USDA..............United States Department of Agriculture
USFS…………United State Forest Service

EXECUTIVE SUMMARY

The project evaluates the potential for bioenergy technology to serve as a market outlet for wood biomass in Colorado's Front Range counties (Boulder, Chaffee, Clear Creek, Custer, Denver, Douglas, El Paso, Fremont, Gilpin, Grand, Huerfano, Jefferson, Lake, Larimer, Las Animas, Park, Pueblo, Saguache, and Teller Counties). The study was prompted by concerns over the biomass fuel levels building up in Colorado's forests, particularly the urban-wildland interface and surrounding forest lands. Forest management efforts are being implemented throughout Colorado, and there are few if any market outlets for the biomass material that is being generated through these efforts.

The objective of the work effort is to investigate economically viable bioenergy outlets for small-diameter wood biomass from appropriate forest thinning projects and to reduce the threat of wildfire in Front Range Communities. There are many uses for biomass thinned from overcrowded forests, though most products require only a very small quantity of wood biomass, relative to the quantities available to be removed. Rather than try to increase production of these low-demand products, one option is to use the forest wastes for the potentially large demands of a biomass power industry.

This project consisted of 5 tasks:

1. Outreach to Communities, Utility Customers and Federal Agencies. Obtain input on public perception of forest restoration activities and biomass power. Conduct a survey of utility customer willingness to pay extra for biomass power and determine federal agency interest in biomass power.
2. Boiler Identification and Survey. Create a map and underlying database of utility and large industrial boilers and smaller facility boilers (within Colorado's Front Range area), substantially complete, and in sufficient detail as to prioritize potential candidates for replacement or refurbishment to use biomass fuel.
3. Biomass Resource Assessment Update. Provide a county level GIS database (within Colorado's Front Range area) of biomass resource availability and cost from forest restoration activities, urban wood residues, and industry residues.
4. Assessment of Biomass Potential. Discuss key opportunities for biomass technology deployment in Colorado.
5. Summary Report and Presentations. Document the results of the entire project and prepare recommendations of the best potential opportunities to develop near-term commercially viable outlets for the large quantities of biomass to be generated from forest restoration activities. This report represents the results of Task 5.

Task 1 – Outreach to Communities, Utility Customers and Federal Agencies

Community Outreach. McNeil staff conducted and participated in several public meetings designed to increase interest in and support for deploying biomass energy technologies in the study area. In August 2002, McNeil and the Colorado State Forest Service organized a forest health/biomass energy meeting that was held in Nederland, Colorado. Details on the content of this meeting are provided later in this report. The meeting led to two bioenergy projects being implemented in the region:

- The first project is a biomass heating and small-scale power demonstration project at the Nederland Community Center. As of October 2003, construction of the biomass energy system is nearly complete. The project will use a wood-fired boiler (procured from Messersmith Manufacturing) to provide heat and hot water for the Nederland Community Center. As part of the project, Delta Dynamics of Boulder, Colorado will install a 30 kW steam microturbine at the site to produce electricity for a pre-defined period of time. The microturbine will be interconnected to the utility grid.

- The second project involves developing a wood-fired heating system for a new office complex that Boulder County is building near Longmont, Colorado in 2004. One of the attendees at the Nederland meeting was Therese Glowacki of the Boulder County Department of Parks and Open Space. After the Nederland meeting, Ms. Glowacki asked McNeil staff to present information on biomass energy to county facilities, forestry and engineering staff. As a result of this second presentation, Boulder County conducted a detailed feasibility study of using an automated wood heating system to provide heat for their new office complex.[1] The results of the feasibility study were positive, and in July 2003, the Boulder County Commissioners gave formal approval to move ahead with including a wood heating system in their design and construction of the new office complex. It is expected that the system will be installed in 2004.

McNeil staff also made several additional public presentations to promote forest/health biomass energy in Colorado. These meetings included: 2002 Colorado Renewable Energy Conference, held in Colorado Springs in June 2002; Colorado Renewable Energy Society monthly meeting held in Lakewood, in August 2002; Club 20 Annual meeting held in Grand Junction in March 2003; West Slope Biomass Energy Meeting in Rifle, held in March 2003; and the 2003 Colorado Renewable Energy Conference held in Montrose, in June 2003. An additional meeting, conducted as part of another project, was held in Dillon in June 2003.[2]

Utility Customer Survey. McNeil staff designed and implemented a brief telephone survey to measure the attitudes and opinions of utility customers on biomass energy, forest health, and their willingness to pay a premium on their energy bill to purchase biomass electricity from their local utility. There were 100 respondents to the survey. A total of 62 percent said they would be willing to pay more for electricity produced from forest thinnings. Fifty-five percent of the respondents indicated they would be willing to pay more than $10 per month extra to support biomass electricity development. The full details of the survey are presented in Section 2.2.

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[1] McNeil Technologies, Inc,. *Feasibility Study of a Biomass Energy System for Boulder County Parks Department.* June 2003. Available from the Boulder County Department of Parks and Open Space.

[2] McNeil Technologies, Inc. *Evaluating Biomass Utilization Options for Colorado: Summit and Eagle Counties.* August 2003. Sponsored by the Colorado Governor's Office of Energy Management and Conservation and the U.S. Department of Energy, Western Regional Biomass Energy Program. www.westbioenergy.org

Federal Agency Interest. The federal government has a goal of increasing renewable energy use to 2.5 percent of total federal energy use by 2005. Presently, renewable energy use makes up approximately 0.4 percent of total federal energy use.[3] Federal agencies will be seeking to boost purchases of renewable energy or green tags to help meet this goal. The federal government has several efforts devoted to promoting and facilitating green power purchases by federal agencies.

There are potential opportunities to sell green power or green tags to federal agencies in Colorado. However, before federal agencies can be approached to purchase green tags, biomass power must be generated. The Western Area Power Administration (WAPA) is currently aggregating federal customers who may be interested in purchasing green tags. The contact at WAPA who is overseeing this effort is Mike Cowan. He can be reached at 720-962-7245. The U.S. Environmental Protection Agency (EPA) has established the Green Power Partnership Program to assist federal agencies and companies in procuring green power for their facilities.

Task 2 Activities - Boiler Identification

For Task 2, McNeil staff created an inventory of existing boilers in the Front Range. The purpose of this effort was to identify facilities that could potentially utilize biomass resources in an existing boiler through co-firing biomass and fossil fuel. The effort focused on identifying coal-fired power plants and cement plants. An additional effort was made to identify large commercial and industrial boiler systems, as well as small to medium commercial facilities. The list of large facilities is contained in Appendix C, and the list of all other facilities is located in Appendix D. The boiler information has been input into a GIS system, and a map of their locations can be found in Section 3 of this report. These facilities are potential locations where stakeholders can pursue biomass energy projects.

McNeil spoke to Xcel Energy staff about their interest in exploring co-firing of wood and coal. Xcel stated that they were not interested in doing anything that would cause them to modify their air permits as they did not wish to go through that process with EPA.

Two facilities in Colorado are currently exploring co-firing. The Holcim Cement facility in Florence, Colorado has initiated efforts to co-fire forest thinning biomass and coal in its cement kilns. The facility has purchased separate handling equipment for the wood fuel and plans to begin using biomass in late 2003.

The W.N. Clark power plant in Cañon City, Colorado conducted co-firing tests in 2001 and 2002. The plant, which is owned and operated by Aquila, Inc., plans to resume co-firing in 2004. W.N Clark is already permitted to burn both wood and coal, thus they do not have the same concerns as does Xcel regarding their air permits.

Aquila is working with OEMC (through a grant from the U.S Department of Energy) to develop a forest biomass green tag program. This program will seek to obtain third party green power

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[3] Crawley, Anne Sprunt. (April 2, 2002). Framework for Meeting Federal Renewable Energy Goal. U.S. Department of Energy, Federal Energy Management Program. On-line: http://www.eren.doe.gov/femp/techassist/pdf/anne_crawley_framework.pdf Accessed September 30, 2002.

certification for the biomass portion of the electricity produced from co-firing forest biomass and coal. If this certification is obtained, Aquila will be able to sell tradable renewable certificates (TRCs) on the open market. This means that Aquila may be able to obtain a premium for their biomass, which will help them offset the higher costs of biomass fuel as compared to coal. Additional information on TRCs, green tags, and green power is contained in Section 5.1.4 of this report.

Task 3 – Biomass Resource Assessment Update

For Task 3, McNeil staff compiled up to date information on the biomass resource potential along the Front Range. To accomplish this task, we evaluated the biomass resource potential from urban wood residues (from land clearing, commercial tree care, lawn & garden, landscaping, pallet manufacturing and wood products manufacturing establishments) and forest biomass (based on forest land within the Red Zone in Front Range counties with slopes less than 40 percent and assuming that five percent of the total is managed annually to reduce fuels). To estimate urban wood residues from the number of businesses, we used residue generation factors specific to each business type. It was assumed that 57 percent of the urban wood resource.

For forest biomass, we calculated county-level biomass yields using USFS Forest Inventory & Analysis Database information on standing tree volumes with diameter classes than 11 inches diameter at breast height, then assumed that 5 green tons would remain on-site for wildlife habitat and soil conservation purposes.

Total estimated annual biomass resource generation in the Front Range is 607,364 bone dry tons (BDT). Of the total, forest biomass makes up 58 percent of the total resource. Urban sources make up the remaining 42 percent.

Task 4 – Assessment of Biomass Potential

The biomass resource is distributed throughout the study area, but with heavy concentrations in Grand, Boulder, Gilpin, Jefferson and El Paso counties (Figure ES-1). In Grand County, most of the resource is from forest management; in Boulder, Gilpin, Jefferson and El Paso counties the source of the biomass is more evenly distributed among urban and forest sources.

Using 75 percent of the biomass resource potential, allowing for quantities that may not be recoverable, could support 47.6 megawatts (MW) of biomass-based renewable power generation. The amount of power generated from this capacity, an estimated 337 gigawatt-hours (GWh) could support the energy needs of 46,000 households.

Under Task 4, McNeil staff created several GIS overlays showing the location of boilers and the biomass resources available on a county-level. Figure ES-1 shows the locations of power plants that could be potential sites for co-locating biomass power generation capacity. Coal-fired boilers are also potential sites where wood could be co-fired with coal in existing generating facilities.

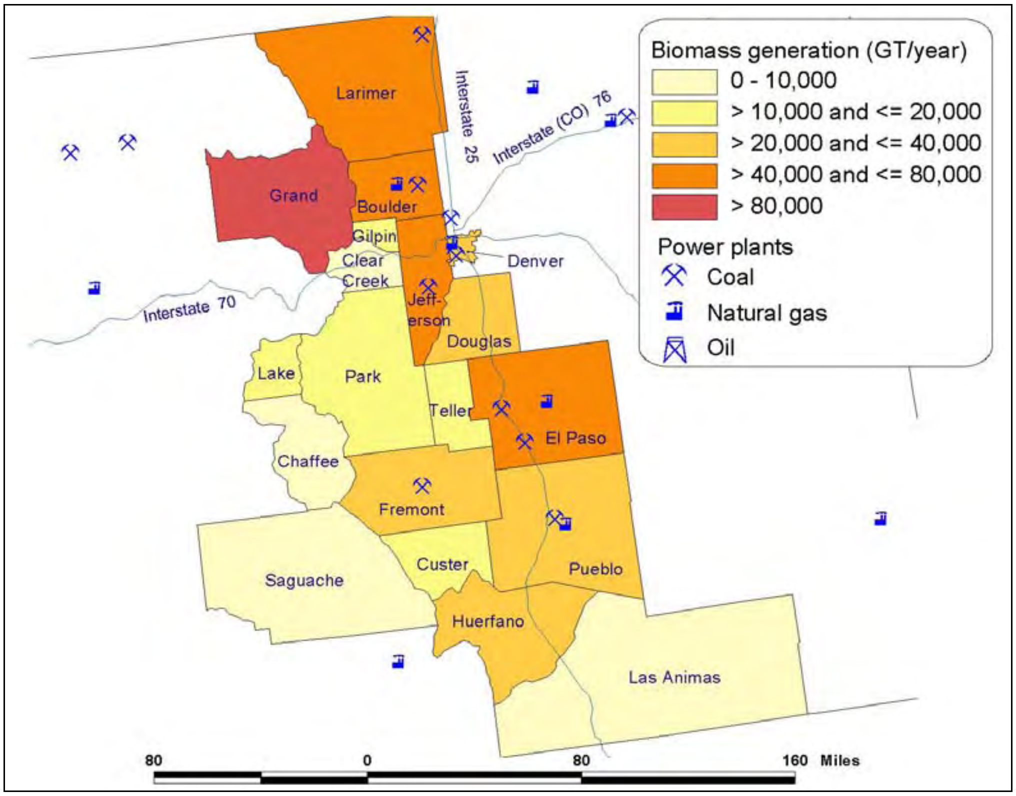

Figure ES-1. Map of Biomass Resource Potential

The total capacity that can be installed economically will require site-specific feasibility assessments. The results of this study can support site-specific feasibility assessments. Key resource areas include Grand, Boulder, Jefferson and El Paso counties. However, other communities have an existing resource base that can support a variety of other smaller biomass-based heating and product manufacturing technologies.

Summary and Recommendations

Thermal Applications – Facility Heating

Facility heating is the near term "winner" and as such deserves special attention. Federal and state efforts to incorporate biomass heating (both water and space) in new and retrofitted facilities is both cost-effective and will further the biomass industry. Importantly, the OEMC can work to establish recognition for biomass within the context of the *Rebuild Colorado* program. Incorporating biomass technologies within the Leadership in Energy and Environmental Design (LEED) System will help provide a foundation for architects, planners, and purchasing agents to include biomass systems in their design process (biomass is not presently a recognized renewable source in the LEED program). The LEED System is a voluntary, consensus-based national standard for developing high-performance, sustainable buildings. Members of the U.S. Green Building Council representing all segments of the building industry developed LEED and continue to contribute to its evolution. Additional information on LEED can be located at http://www.usgbc.org/LEED/LEED_main.asp.

Public Outreach

State, federal and local agencies should continue to conduct conferences, workshops and public meetings organized around biomass energy and the link to hazardous fuels reduction efforts. It is essential to sustain the emerging effort by educating consumers and continuing to share technical information to enable the emerging biomass industry to survive. Land management agencies and the public must recognize that there are multiple beneficiaries of fire mitigation work (e.g. water management agencies, recreation, tourism, homeowners, hunters/fishers, general public).

Public policy actions

Biomass energy stakeholders should continue to work together to promote public policies and projects that will increase biomass energy deployment. Parties should continue to monitor any RPS legislation that is introduced during the next legislative session. Biomass energy stakeholders should review the definition of biomass energy and ensure that it is acceptable. Further, biomass power generation should be placed on an equal footing with other renewables by including output rather than nameplate capacity to account for the high capacity factor of biomass.

Biomass fuel supply

The USFS and other landowners should continue to work to implement hazardous fuel reduction projects where they are needed throughout the Front Range. For a biomass fuel supply infrastructure to develop, agencies and landowners must be willing and have the budget to enter into long term stewardship contracts for thinning. This will provide some measure of assurance to a prospective biomass energy facility developer that a long-term fuel supply contract could be obtained. The concept of cost shifting should be explored further – how can the costs of thinning be spread out over the largest number of beneficiaries? The proposed fuel supply credit is one mechanism that is intended to accomplish this objective.

A biomass energy plant will not be able to pay for the full costs of biomass generated from forest thinning and still be able to produce electricity at a price that is competitive in today's wholesale power markets. Either the cost of fuel and/or power generation must be reduced, or the selling price of electricity must be increased. In California, most biomass plants typically pay for transportation only. If the production tax credit and biomass fuel credit survive in the federal Energy Bill, it will help with the economics of a potential facility.

Green power marketing / purchases

Stakeholders and interested parties should encourage existing green power programs operating in the state to include biomass energy in their portfolio mix. Also, interested agencies should fully support Aquila's efforts to develop their forest biomass green tag program. If this program can be successfully established, it could help overcome some of the economic challenges of biomass energy as well as serve as a model for the entire western U.S. National level groups could also be approached to become initial purchasers of the tags. If certified TRCs from forest biomass become available, federal agencies in the Front Range could be approached to purchase the tags. The USFS, BLM, DOE, DOD, EPA, National Park Service and others could help meet the federal 2.5 percent renewable goal, and simultaneously support the development of a market outlet for forest biomass.

Electric utility efforts

Stakeholders should work with the state's electric utilities to encourage their support for the implementation of biomass distributed generation projects. State outreach efforts to utilities could be coordinated around the following topics:

- Conduct a study of the economic and electrical system benefits that utilities may realize through the development of distributed generation at strategic locations within their service area.
- Evaluate whether there are any strategic locations or critical facilities that could install a small biomass power plant. Most of the time, the plant would operate as a normal power plant. However, in the case of an emergency, the facility would have back-up power that could allow its operations to continue in the event of a major power outage or other fuel supply disruption.
- Document, evaluate and attempt to standardize utility interconnection requirements for small- to medium-sized generators of biomass energy in Colorado.
- Encourage Xcel and Tri-state G&T to include electricity produced from biomass as a new supply resource in their green power programs.

1. INTRODUCTION

1.1 Purpose

The purpose of this report is to support the US Forest Service (USFS) objective of reducing the potential for wildfire in the Front Range of Colorado. One means of reducing the threat of wildfires is to conduct forest thinning measures to clear out woody materials that act as fuel. Forest thinning can be a costly undertaking, but it becomes more economically viable if the by-products of thinning (biomass) can be used to generate useful energy, either thermal or electrical or both (co-generation). This report considers whether enough biomass would be available in the Front Range area to support a biomass-fired heating or power plant, and if so, what the potential size of such a power plant might be, and to examine, at a preliminary stage, the economics of such a plant.

1.2 Project Need

Hazardous biomass fuels continue to accumulate on both public and private lands, creating the potential for catastrophic wildfires. Forest managers and land owners have realized they must address this growing threat by reducing fuel loads through a combination of mechanical thinning and prescribed burning. Mechanical thinning treatments result in large quantities of small diameter biomass that currently has little or no market value. Growing concerns over air quality and fears of prescribed burns getting out of control also lead to an increased need to remove biomass from the forest.

Removing a portion of these materials can help prepare forest restoration sites for the safe application of prescribed burning and help reduce overall fuel loads. In addition, creating market outlets for the material may help reduce management costs for both public land management agencies and private landowners. Biomass-based generation, cogeneration and facility heating technologies have the potential to support forest ecosystem restoration efforts in the western U.S. by providing market outlets for biomass. It is important to assess the characteristics of the current and potential stream of feedstock as the first step in finding a potential market outlet and beneficial use for these biomass residues.

1.3 Study Area

This report documents the results of biomass energy assessment conducted for the Colorado Front Range. The Front Range is broadly defined to include the areas from Fort Collins in the north to Pueblo in the south, and from Lake County in the west to approximately the I-25 corridor in the east. Counties included in the study area include Boulder, Chaffee, Clear Creek, Custer, Denver, Douglas, El Paso, Fremont, Gilpin, Grand, Huerfano, Jefferson, Lake, Larimer, Las Animas, Park, Pueblo, Saguache, and Teller.

Figure 1-1 shows the outline of the counties included in the study, along with a depiction of the "Red Zone" areas that are at risk for catastrophic wildfire.

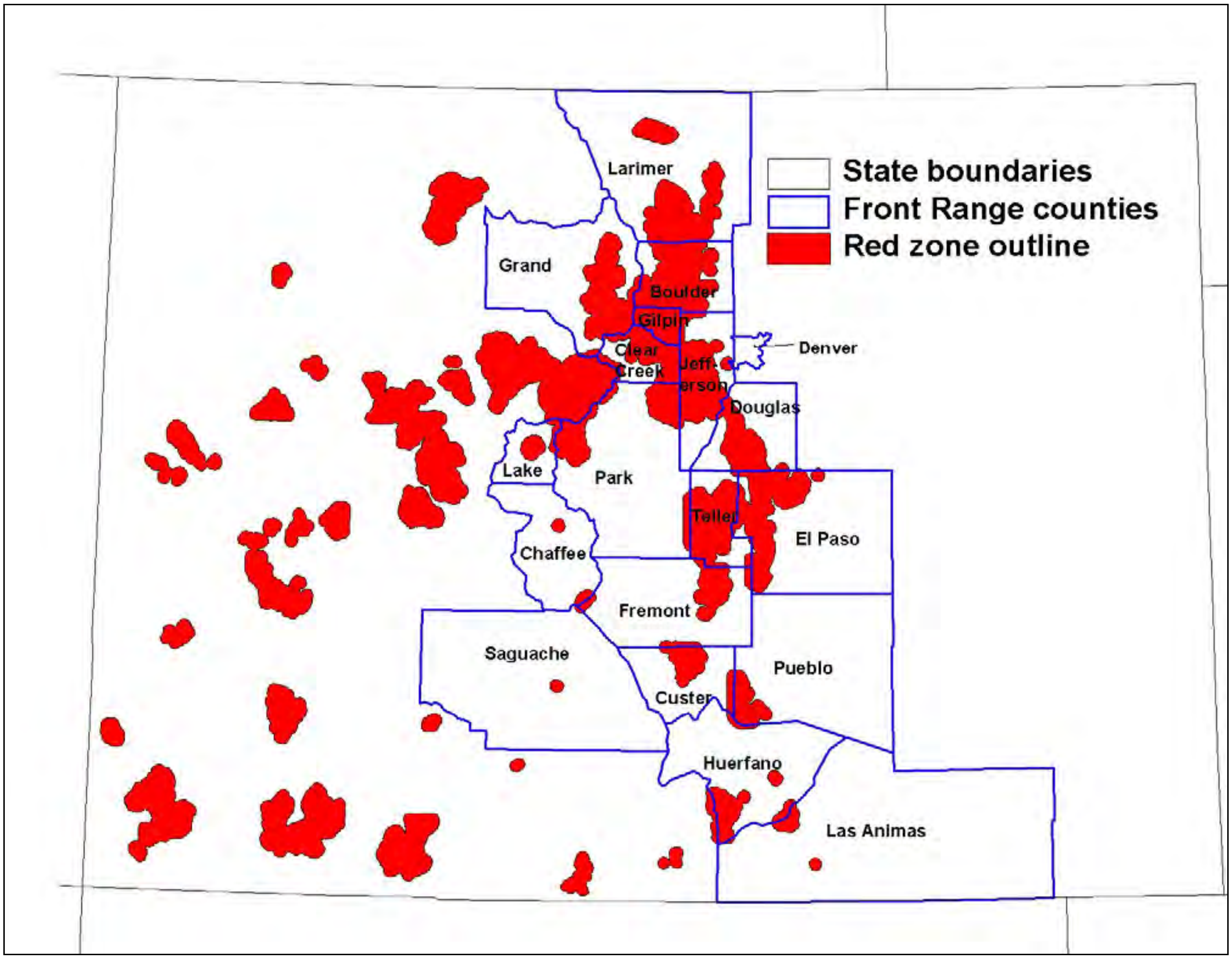

Figure 1-1. Study area and Red Zone map

1.4 Project Team

McNeil Technologies, Inc. conducted the primary work on this project. At McNeil, Scott Haase was the Project Manager. Randy Hunsberger, Tim Rooney and Scott Haase were the primary authors of this report.

1.5 Project Objectives

The goal of the project was to promote the development of economically viable outlet markets for small-diameter wood biomass to reduce fire risks and improve forest conditions in the Front Range urban-wildland interface in Colorado. In support of the goal, there were several objectives:

- Conduct public outreach to promote biomass energy, conduct a survey of utility customers, and assess federal agency activities related to renewable energy procurement
- Develop a database of solid fuel and natural gas boilers in the area
- Determine the biomass resources generated and available in the study area
- Characterize the biomass resource in terms of type, estimated physical and chemical characteristics, and long term availability
- Develop GIS maps of biomass resources and of boilers in the Front Range
- Compile all of the information into a final report, and present the results at a public meeting

1.6 Report Structure

The remainder of this report contains a summary of the technical work and activities performed on this project. Section 2 discusses activities performed in support of community outreach, including information on a public meeting, results of a telephone survey, and an assessment of federal agency activities related to renewable energy usage goals and green power procurement.

Section 3 contains summary information and locations for large industrial and commercial boilers in the Front Range. Section 4 contains the biomass resource assessment for both forest residues and urban wood waste. Section 5 discusses biomass energy technologies, green power and green tags, biomass economics, and provides an overview of the technical potential for biomass power generation along the Front Range. Section 6 provides conclusions and recommendations for future efforts that OEMC and the USFS may wish to support. A bibliography of reports and references used in the study is provided. Finally, there are several Appendices that contain additional technical information related to the project.

2. OUTREACH TO COMMUNITIES, UTILITY CUSTOMERS AND FEDERAL, AGENCIES

This task focused on outreach to communities, utility customers, and federal agencies.

Community meetings were held to explore regional interest in power generation from forest biomass. Section 2.1 summarizes the meetings. Appendix A provides more detailed information.

A survey was conducted to determine public perceptions of forest restoration activities and biomass power, and to asses utility customer willingness to pay extra for biomass power. In Section 2.2, the data are summarized and the potential effect of public education regarding biomass technology on that perception is discussed.

Federal agency interest and actions toward biomass power is reviewed in Section 2.3.

2.1 Community Meetings

Meetings were held in Nederland, Colorado, beginning in August of 2002. The purpose of meetings was to introduce interested parties to the potential use of biomass and small diameter material from forest restoration and fuel reduction projects. The first meeting, held on 2002-08-30 consisted of a morning and an afternoon session. The focus of the morning session was the application of biomass to energy production and use, small diameter marketing and utilization, and forest restoration/wildfire mitigation projects. A tour of the Winiger Ridge Ecosystem Management Project was conducted in the afternoon.

The meeting was sponsored by OEMC, the USFS, CSFS and the Nederland Committee for Forestry and Wildfire Mitigation.

Presenters included:

- Ed Lewis, Deputy Director, Governor's Office of Energy Management and Conservation,
- Dr. Merrill Kaufmann, Research Forest Ecologist, USFS,
- Dr. Kurt Mackes, Assistant Professor, Colorado State University/CSFS,
- Scott Haase, Program Manager, McNeil Technologies,
- Dan Len, Small Diameter Utilization Program, USFS,
- Gary Sanfacon, Facilitator, Peak to Peak Healthy Communities Project,
- Christine Walsh, District Ranger, U.S. Forest Service, and
- Craig Jones, Interagency Project Coordinator, Winiger Ridge Project, CSFS

Copies of workshop materials are included in Appendix A.

The result of these meetings included two projects. The town of Nederland decided to install a biomass-fired heating system in their community center. This project, which is currently being installed, includes a demonstration of a Delta Dynamics' steam microturbine, powered from the biomass boiler.

A second project resulting from these meetings was a feasibility study for a biomass-fired heating system for a new Boulder County Parks and Open Space office building. That study found that the system, which would receive most of its fuel from thinning projects on Parks and Open Space land, is economically feasible at current natural gas rates. Installation of a biomass-fired boiler has been approved by the Boulder County Commissioners, and should take place in 2004.

2.2 Customer Survey

A survey was conducted to obtain data on public attitudes regarding energy generation from biomass. A second objective of the survey was to gauge public sentiment towards forest management activities aimed at reducing catastrophic wildfires. A third aim of the survey was to estimate the number of customers willing to pay a premium for electricity generated from biomass sources—and to quantify the dollar amount of that premium. Survey questions are listed in this section, and a copy of the survey is included in Appendix B.

A questionnaire was created using Teleform software, and answers were obtained through random telephone calls. The following are the results of attempted and successful phone calls:

Result	**Count**	**Percent**
No answer	356	55.4%
Disconnected	81	12.6%
Busy	23	3.6%
Declined to participate	83	12.9%
Participated	100	15.6%
Total	**643**	100%

Only about 16% of all phone calls resulted in a completed survey. However, of those calls that were answered by a live person, 55 percent participated in the survey. Most of the calls were made between 9 AM and 5 PM on weekdays, which may have influenced the results. About 30 percent of the calls were made in the evenings.

The Front Range study area includes 19 counties, with a total of about 1,100,000 households. The survey included two counties that are not in the Front Range study area—Summit and La Plata. These counties both have recently experienced fires and are vulnerable to fires in the future.

Table 2-1 shows the total number of households in the extended study area (including Summit and La Plata Counties), the number of households in the sample frame,[4] the number of survey participants from each county, and the relative percentage of representation for each county.[5]

[4] The *Sample Frame* was a database of names, addresses, and phone numbers for 1,000 randomly chosen households. The data for the sample frame came from InfoUSA.com. The *Survey Samples* were drawn from this list.

Table 2-1. Survey population and sample size, by county

County	# Households	# in Sample Frame	# in Sample	Sample, as % of Frame
Boulder	119,900	69	7	10.1
Chaffee	8,392			
Clear Creek	5,128	10	4	40.0
Custer	2,989			
Denver	251,435			
Douglas	63,333			
El Paso	202,428			
Fremont	17,145			
Gilpin	2,929			
Grand	10,894	4		0.0
Huerfano	3,082			
Jefferson	206,067	217	18	8.3
Lake	3,913			
La Plata	20,765	370	38	10.3
Larimer	105,392	149	13	8.7
Las Animas	7,629			
Park	5,894	53	5	9.4
Pueblo	54,579			
Saguache	2,300			
Summit	24,201	43	3	7.0
Teller	10,362	85	12	14.1
Total	1,128,757	1000	100	10.0

The survey consisted of six questions, as follows:

1. **Are you aware of the wildfire threat facing Colorado's forests?**
2. **Do you live in an area where you and your property could be directly threatened by a large forest fire?**
3. One way to reduce the threat of wildfires is too thin forest by removing small trees and brush that fuel wildfires. **Have you heard of forest thinning?**
4. Wood removed from forest thinning can be used to create electricity. **Would you be willing to buy electricity from your utility that is generated from wood remove from the forests?**
5. **Which of these potential benefits of using wood removed from Colorado forests do you feel would be most important?** [*See choice list, below*]

[5] For a sufficiently large and randomized survey, the relative representation for each county should be 10 percent. Clear Creek County is over-represented, and Grand County is under-represented, in these results.

6. Electricity generated from wood removed from the forests is more expensive than regular electricity. **Would you be willing to pay more for electricity produced from forest thinnings if it could be generated in a way that protects the environment?**

   [**If yes, how much extra would you be willing to pay on a monthly basis?**]

2.2.1 Brief Summary of Results

This section presents a brief summary of the responses to each of the six questions in the survey.

1. Are you aware of the wildfire threat facing Colorado's forests?

Almost everyone surveyed said that they were aware of the wildfire threat, even though the wildfire season for 2003 was not as bad as 2001 or 2002.

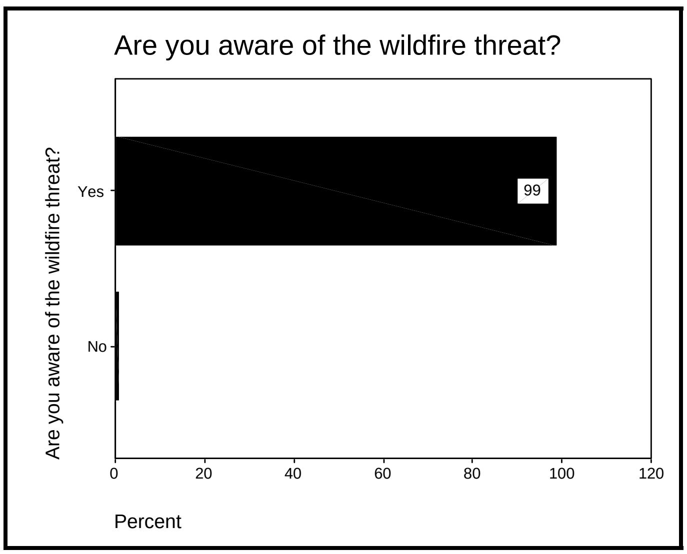

Figure 2-1. Results for Question 1

2. Do you live in an area where you and your property could be directly threatened by a large forest fire?

The survey areas are largely wooded, and are in close proximity to state and national forests, therefore it is not surprising that 78 percent of the survey participants said that a large forest fire could threaten their property.

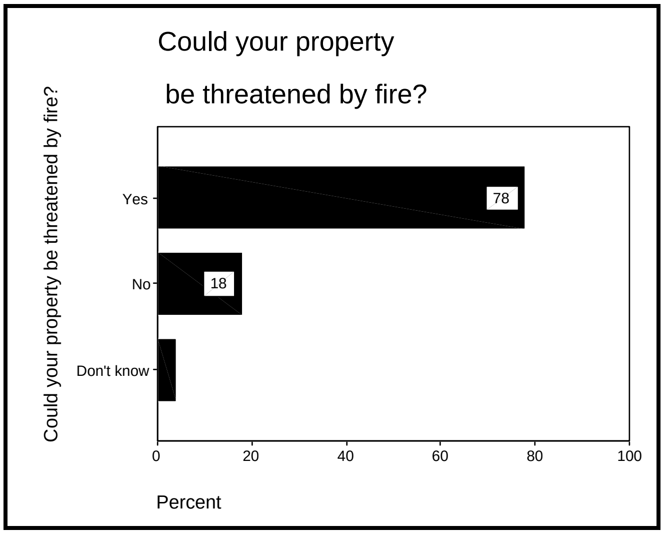

Figure 2-2. Results for Question 2

3. One way to reduce the threat of wildfires is too thin forest by removing small trees and brush that fuel wildfires. **Have you heard of forest thinning?**

Only six percent of the survey respondents were not familiar with forest thinning.

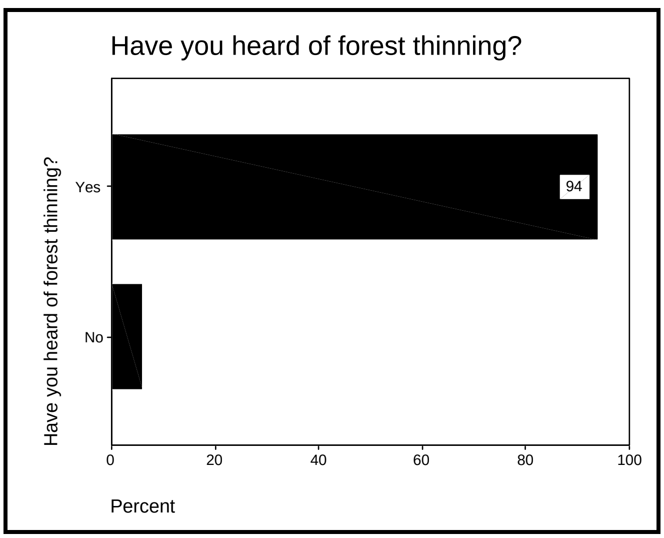

Figure 2-3. Results for Question 3

4. Wood removed from forest thinning can be used to create electricity. **Would you be willing to buy electricity from your utility that is generated from wood removed from the forests?**

A relatively high percentage of respondents (29 percent) answered that they didn't know if they would purchase electricity generated from wood removed from forests. It is probable that some of these would turn to "yes" if there were no cost penalty, and "no" if there were an extra charge for supporting this type of power generation.

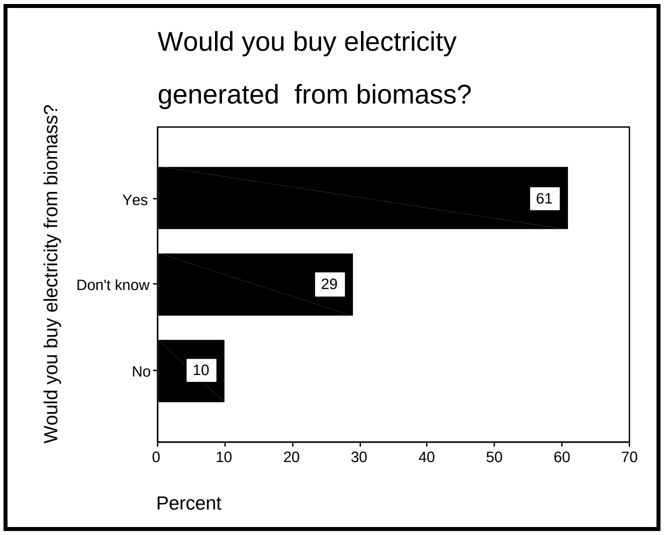

Figure 2-4. Results for Question 4

5. **Which of these potential benefits of using wood removed from Colorado forests do you feel would be most important?**

Figure 2-5 shows the results, in descending order of selection, for Question 5. The two related choices, "Reducing the risk of wildfires" and "Improving forest health" were selected by 65 percent of respondents.

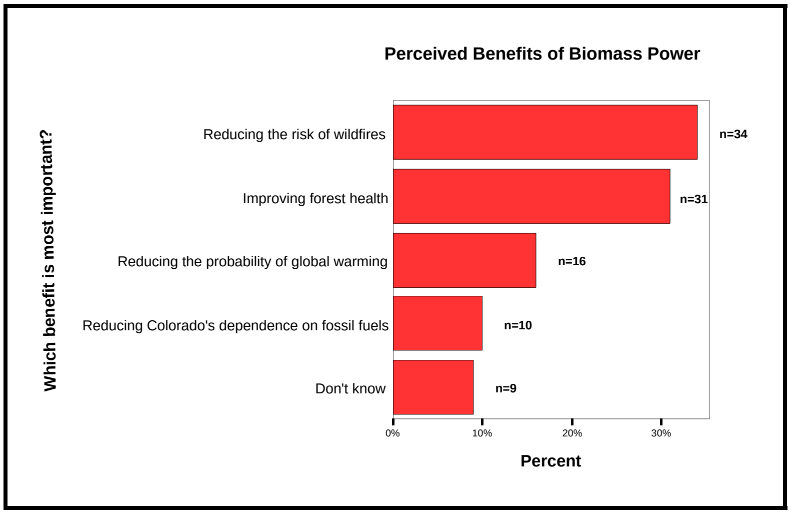

Figure 2-5. Results for Question 5

Question 5 presented some difficulties. The possible answers were:

- Improving forest health
- Reducing the risk of wildfires
- Reducing Colorado's dependence on fossil fuels
- Reducing the risk of global warming
- Don't know

Many of the respondents answered that these were *all* important benefits and had trouble choosing an answer. Some respondents were also unsure about the meaning of “forest health.” The largest number of respondents (34 percent) chose “Reducing the risk of wildfires,” followed closely by “Improving forest health” (31 percent of respondents). In contrast, only 10 percent chose “Reducing Colorado’s dependence on fossil fuels.” It is possible that the context of the survey – forest fire prevention – may have biased the answers. In addition, the answers were not mutually exclusive. For example, mitigating forest fires also reduces global warming. “Improving forest health” is not independent of “reducing the risk of wildfires.”

6. Electricity generated from wood removed from the forests is more expensive than regular electricity. **Would you be willing to pay more for electricity produced from forest thinnings if it could be generated in a way that protects the environment?**

The majority of people surveyed said that they would be willing to pay extra for electricity generated from forest thinning projects.

This is an important question, and is discussed in more detail in Section 2.2.2, Assessment of Utility Customer Opinions.

[6a **If yes, how much extra would you be willing to pay on a monthly basis?**]

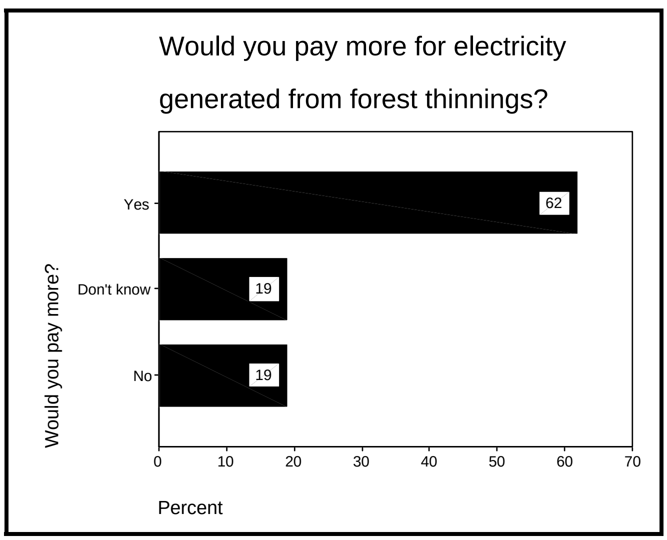

Figure 2-6. Results for Question 6

Figure 2-7 shows the distribution of amounts that survey participants indicated that they would pay, in addition to their normal electricity bill. This is also discussed in greater detail in Section 2.2.2.

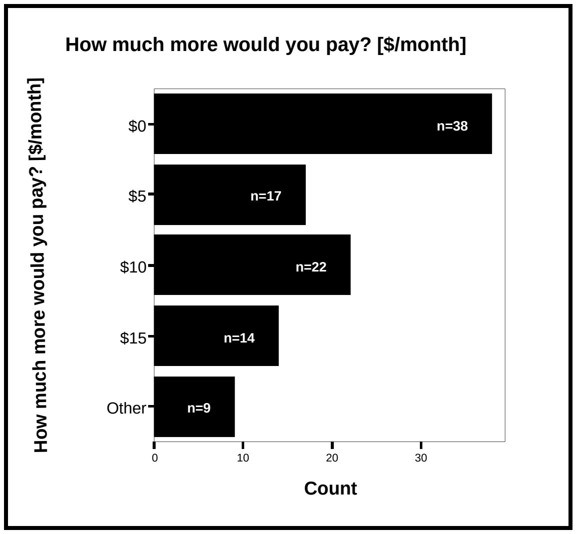

Figure 2-7. Additional amount that survey respondents were willing to pay for electricity generated from biomass

2.2.2 Assessment of Utility Customer Opinions

One of the most important results of the survey is the estimate of how many people are willing to pay extra for "green" power generated from biomass, and how much extra they are willing to pay. This was assessed in Question 6.

Overall, 62 percent of the respondents said that they would be willing to pay more for electricity generated from forest thinnings. Figure 2-8 shows the responses to Question 6 for the entire survey set.

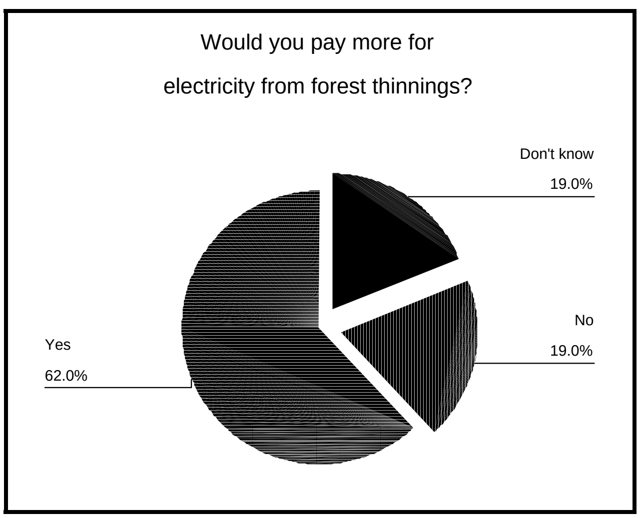

Figure 2-8. Percentage willing to pay more for electricity generated from forest thinnings

Table 2-2 is a breakdown, by county, of the responses to Question 6. The counties with the largest percentage stating that they would be willing to pay more for electricity generated from forest thinnings include Park County (80 percent), Clear Creek County (75 percent) and Boulder County (71 percent). Jefferson County has the lowest percentage of positive responses, at 39 percent. Section 2.2.3.3 discusses the potential sampling error for the entire survey population, and for each county.

Table 2-2. Responses to Question 6, by county

County		Would you pay more for electricity from forest thinnings?			
		Don't know	**No**	**Yes**	***Total***
Boulder	Count		2	5	**7**
	% within County		28.6%	71.4%	
Clear Creek	Count	1		3	**4**
	% within County	25.0%		75.0%	
Jefferson	Count	5	6	7	**18**
	% within County	27.8%	33.3%	38.9%	
La Plata	Count	7	5	26	**38**
	% within County	18.4%	13.2%	68.4%	
Larimer	Count	2	2	9	**13**
	% within County	15.4%	15.4%	69.2%	
Park	Count		1	4	**5**
	% within County		20.0%	80.0%	
Summit	Count		1	2	**3**
	% within County		33.3%	66.7%	
Teller	Count	4	2	6	**12**
	% within County	33.3%	16.7%	50.0%	
Total	Count	**19**	**19**	**62**	**100**
	% within County	19.0%	19.0%	62.0%	

Table 2-3 shows the amount that respondents stated they would be willing to pay extra for electricity generated from forest thinnings, by county. It is similar to Table 2-2, but quantifies the amount that respondents indicated that they would be willing to pay.

Including those that choose the “other” option[6], 45 percent of respondents indicated that they would pay an extra $10 or more per month for electricity generated from forest thinnings.

[6] Respondents choosing “other” universally indicated that they would pay more than $15/month extra.

Table 2-3. Cross-tabulation of amount willing to pay, by county

			How much more would you pay? [$/month]					
			$0	$5	$10	$15	Other	Total
County	Boulder	Count	2		3	2		7
		% within County	28.6%		42.9%	28.6%		
	Clear Creek	Count	1	1	1	1		4
		% within County	25.0%	25.0%	25.0%	25.0%		
	Jefferson	Count	11	1	5	1		18
		% within County	61.1%	5.6%	27.8%	5.6%		
	La Plata	Count	12	9	8	6	3	38
		% within County	31.6%	23.7%	21.1%	15.8%	7.9%	
	Larimer	Count	4	3	1	3	2	13
		% within County	30.8%	23.1%	7.7%	23.1%	15.4%	
	Park	Count	1		2	1	1	5
		% within County	20.0%		40.0%	20.0%	20.0%	
	Summit	Count	1		1		1	3
		% within County	33.3%		33.3%		33.3%	
	Teller	Count	6	3	1		2	12
		% within County	50.0%	25.0%	8.3%		16.7%	
Total		Count	38	17	22	14	9	100
		% within County	38.0%	17.0%	22.0%	14.0%	9.0%	

Table 2-4 is a cross-tabulation of Question 2 (“Do you live in an area where you and your property could be directly threatened by a large forest fire?”) with Question 6 (Would you be willing to pay more for electricity produced from forest thinnings if it could be generated in a way that protects the environment?”). One might expect that those whose property was likely to be threatened by fire would be more likely to be willing to pay more for electricity generated from forest biomass, but this is not indicated by the survey results. Instead, that group was less likely to be interested in paying more.

Table 2-4. Cross-tabulation of Questions 2 and 6

			Would you pay more for electricity from forest thinnings?			
			Don't know	**No**	**Yes**	***Total***
Could your property be threatened by fire?	**Don't know**	Count	1	1	2	**4**
		%	25.0%	25.0%	50.0%	
	No	Count	4	2	12	**18**
		%	22.2%	11.1%	66.7%	
	Yes	Count	14	16	48	**78**
		%	17.9%	20.5%	61.5%	
	Total	Count	**19**	**19**	**62**	**100**
		%	19.0%	19.0%	62.0%	

Table 2-5 cross-tabulates Question 5 (“Which of these potential benefits of using wood removed from Colorado forests do you feel would be most important?”) with Question 6. Of the 10 people who choose “Reducing Colorado’s dependence on fossil fuels” as being most important (Question 5), 80 percent said that they would pay more for electricity from forest thinnings. Those that selected “Improving forest health” for Question 5 had a similar positive response to

Question 6, at 77 percent. Interestingly, of those respondents that said that "Reducing the risk of wildfires"[7] was the most important benefit, only 53 percent said that they would pay more for electricity generated from forest thinnings.

Table 2-5. Cross-tabulation of Questions 5 and 6

			Would you pay more for electricity from forest thinnings?			Total
			Don't know	No	Yes	
Which benefit is most important?	Don't know	Count	4	4	1	9
		%	44.4%	44.4%	11.1%	100.0%
	Improving forest health	Count	6	1	24	31
		%	19.4%	3.2%	77.4%	100.0%
	Reducing Colorado's dependence on fossil fuels	Count	1	1	8	10
		%	10.0%	10.0%	80.0%	100.0%
	Reducing the probability of global warming	Count	3	2	11	16
		%	18.8%	12.5%	68.8%	100.0%
	Reducing the risk of wildfires	Count	5	11	18	34
		%	14.7%	32.4%	52.9%	100.0%
Total		Count	19	19	62	100
		%	19.0%	19.0%	62.0%	100.0%

Table 2-6 cross-tabulates the additional amount that people state that they are willing to pay for electricity generated from forest thinnings with the responses to Question 5. Overall, 45 percent of all respondents said that they would pay an additional $10 or more every month (most of those answering "Other" said that they would pay more than $15/month). Of those stating that "Improving forest health" was most important in Question 5, 61 percent said that they would pay $10 or more every month. Of those stating that "Reducing the risk of wildfires" was most important, only 35 percent were willing to pay $10 or more per month.

Table 2-6. Cross-tabulation of Question 5 with "How much would you pay?"

			How much more would you pay? [$/month]					Total
			$0	$5	$10	$15	Other	
Which benefit is most important?	Don't know	Count	8			1		9
		Row %	88.9%			11.1%		
	Improving forest health	Count	7	5	9	7	3	31
		Row %	22.6%	16.1%	29.0%	22.6%	9.7%	
	Reducing Colorado's dependence on fossil fuels	Count	2	4	1	2	1	10
		Row %	20.0%	40.0%	10.0%	20.0%	10.0%	
	Reducing the probability of global warming	Count	5	2	6	2	1	16
		Row %	31.3%	12.5%	37.5%	12.5%	6.3%	
	Reducing the risk of wildfires	Count	16	6	6	2	4	34
		Row %	47.1%	17.6%	17.6%	5.9%	11.8%	
Total		Count	38	17	22	14	9	100
		Row %	38.0%	17.0%	22.0%	14.0%	9.0%	100.0%

[7] "Reducing the risk of wildfires" was the response selected by the largest number of people.

2.2.3 Other Issues

This section contains a short discussion of inconsistent responses, of the "Don't know" answers, and of data error estimates.

2.2.3.1 Inconsistent Responses

Two questions generated conflicting answers; Question 4 asked whether the respondent would be willing to buy electricity generated from wood removed from the forests, and Question 6 asked if they would be willing to pay more for electricity produced from forest thinnings. Those people answering "no" to Question 4 should also have answered "no" to Question 6. However, one third of those answering "no" or "don't know" to Question 4 answered "yes" to Question 6. This leads to the possible conclusions that people either did not answer the questions thoughtfully or that they were influenced by the reading of Question 5. These observations are important in the context of designing a public education effort.

Table 2-7. Cross-tabulation of results for Questions 4 and 6

		Would you pay more for electricity from forest thinnings?			
		Don't know	**No**	**Yes**	***Total***
Would you buy electricity from biomass?	**Don't know**	13	8	8	29
	No	2	3	5	10
	Yes	4	8	49	61
Total		19	19	62	100

2.2.3.2 "Don't know" Responses

Forty-three percent of respondents answered "Don't know" to at least one question. Four questions included "Don't know" as one of the choices: questions 2, 4, 5 and 6. Three respondents choose "Don't know" 3 times, 12 choose "Don't know" for two of the questions, and 28 only choose "Don't know" once. Fifty-seven didn't choose "Don't know" for any question. Figure 2-9 shows the number of "Don't know" responses per person.

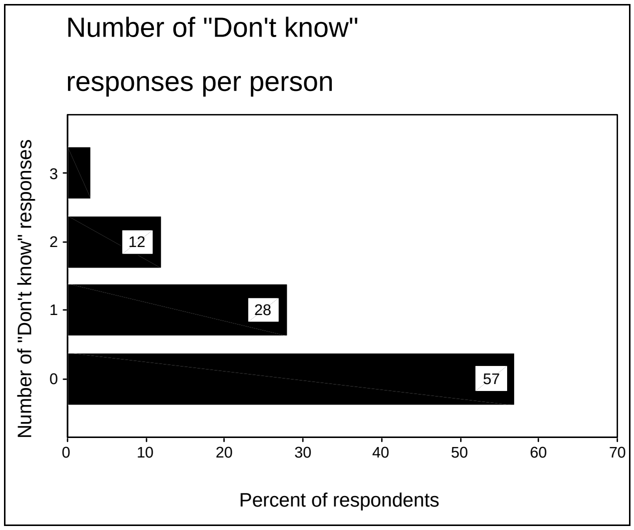

Figure 2-9. Number of "Don't know" responses per person

The question that received the largest percentage of "Don't know" responses was Question 4, at 29 percent, followed by Question 6 at 19 percent. These questions both relate to buying electricity generated from forest thinnings.

The people who choose this answer were also those who were least likely to be willing to pay more for electricity produced using forest thinnings. This may indicate that a program to educate and inform the public about the benefits of forest thinning could significantly boost the support for biomass power, or increase the number willing to pay extra for it.

2.2.3.3 <u>Sampling Error</u>

Sampling error is defined as error stemming from the fact that only a subset of the entire population is surveyed.[8] The equation to calculate the maximum sampling error based on the number of completed surveys for a desired confidence level is given in Equation 1.

Equation 1. Calculating required number of samples.

$$\boxed{B = C * \sqrt{\frac{(Np - Ns)(p)(1-p)}{(Np-1)(Ns)}}}$$

Where:
B = sampling error
Ns = number of completed samples
Np = size of population
P = proportion of population expected to choose one of the two response categories
C = Z statistic associated with the confidence level

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[8] Dillman, Don A., Mail and Internet Surveys: The Tailored Design Method, 2nd Edition. John Wiley & Sons. New York. 2000. p. 205.

Equation 1 assumes that each question has two possible answers. The worst case occurs when the two possible answers are equally likely to be chosen (i.e. each has a 50 percent chance of selection). As the split varies to favor one choice, the sampling error actually decreases. For this reason, this equation gives a conservative estimate of sampling error for questions with more than two choices.

The following values can be used to calculate the sampling error for the survey. There are a total of about 1.1 million households in the survey area (including Summit and La Plata counties). Taking this as the population size (Np), and 100 completed surveys as the sample size (Ns), assuming p = 0.5 (worst case), and using a value of C = 1.96 (corresponding to a confidence level of 95 percent), the sampling error is calculated to be ±10 percent for each question.

Though the survey sampling error for the entire survey area is about 10 percent, the error on a county level is much higher. Table 2-8 shows the sampling error for each county included in the survey. The highest sampling error potential occurs in Summit, Park, and Clear Creek Counties, with an error of 44 to 57 percent. The counties with the lowest sampling error are La Plata (16 percent) and Jefferson (23 percent).

Table 2-8. Sampling error, by county

County	# Households	# in Sample	Error, by County [%]
Boulder	119,900	7	37
Clear Creek	5,128	4	49
Jefferson	206,067	18	23
La Plata	20,765	38	16
Larimer	105,392	13	27
Park	5,894	5	44
Summit	24,201	3	57
Teller	10,362	12	28
Total	**1,128,757**	**100**	**10**

Due to the high sampling error in most of the counties, some of the survey results analysis should be considered suspect. Additional surveys focusing on specific counties may be warranted.

2.3 Federal Agency Information

The US federal government has set a goal of acquiring 2.5 percent of their electricity from renewable sources by 2005. At current consumption rates, this is equal to 1384 GWh per year. As of September, 2003, federal government agencies were using electricity from renewable sources at the rate of about 800 GWh/year[9], meaning that they need to purchase another 534 GWh to meet their goal.

[9] Source: Kevin DeGroat, McNeil Technologies, Springfield, VA. Personal communication.

Table 2-9 shows the sources of electricity purchased as "renewable", and the annual equivalent quantity of electricity purchased from each, by the federal government. Liquid fuels (ethanol and biodiesel) count towards the goal and are converted to GWh equivalents based on energy content.

Table 2-9 Federal purchases of electricity from renewable sources, as of September, 2003

Source	GWh/yr
Solar Thermal	8.7
Biomass Power	92.4
Biomass Thermal	108.4
Wind	18.8
RE Purchase/Credits	295.0
Photovoltaics (PV)	24.7
Ground Source Heat Pump	148.1
Biomass Fuels	104.0
TOTAL	800.2

Table 2-10 shows consumption of electricity from renewable sources by federal agencies in Colorado. These data indicate that federal agencies in Colorado are purchasing electricity generated from renewable sources at a rate of 12.8 GWh per year, with the majority of that by the Denver Wind Purchase Initiative.

Table 2-10 Federal consumption of electricity from renewable sources in Colorado

Federal Agency(ies)	kWh/Year
Current Contracts	
Air Force - Schriever AFB	1,800,000
DOE-GFO, WindSource	294 (2)
DOE-DRO, WindSource	202 (2)
FAA - Denver Air Route Traffic Control Center	40,000
Denver Wind Purchase Initiative (1)	11,000,000
TOTAL	**12,840,496**

Footnotes:

[1] Composed of eighteen agencies

[2] These numbers (200 and 294 kWh/yr) seem low. Data source: NREL.

The Western Area Power Administration ("Western") markets and delivers hydroelectric power and related services within a 15-state region of the central and western U.S. Western is a prominent federal agency affecting the Colorado Front Range and is one of four power marketing administrations within the U.S. Department of Energy whose role is to market and transmit electricity from multi-use water projects. The Western transmission system carries electricity from 55 hydropower plants operated by the Bureau of Reclamation, U.S. Army Corps of Engineers and the International Boundary and Water Commission. Together, these plants have a capacity of 10,600 megawatts.

Western has participated in various Federal non-hydro renewable programs including the US DOE Western Regional Biomass Energy Program, the Supplemental Energy Program, and technical support to its customer base of several hundred utilities. More recently, DOE Secretary Abraham directed Western to develop green tags/renewable power program (June 2002).[10] The Economy Act authorizes agencies to enter into mutual agreements to obtain supplies or services by inter-agency acquisition.[11] The Economy Act provides limited legal authority for Western to purchase power for federal agencies. Initial marketing focused on Western allocation customers, but RECs (renewable energy credits) are available to any federal agency. The Western effort will follow the following Program Steps:

- Sign non-binding Statement of Intent
- Agency renewable requirements aggregated and Western issues RFP (must be in Western's territory)
- Renewable contract signed
- Federal/Western contract signed

Some principles for the program are as follows:

- Western acquires renewables upon request from the agencies, not in advance of request.
- Cost for the renewable power is paid by those requesting the services.
- The purpose is not to compete with the private sector, but to offer renewable energy options.
- Services provided at Western's cost.
- Green benefits retained by customers.
- No resale of renewable resources.

The contact at Western for this program is Mike Cowan. He can be reached at COWAN@wapa.gov or by phone at 720-962-7245. Should a biomass power plant be developed in Colorado, Western could help market the green power or green tags from the plant to interested federal agencies.

The U.S. Environmental Protection Agency (EPA) has established the Green Power Partnership Program to assist federal agencies and companies in procuring green power for their facilities. Additional information on this program can be found at http://www.epa.gov/greenpower/

Agencies such as the USFS and BLM could purchase green tags from a biomass facility through this program.

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[10] Chandra Shah, National Renewable Energy Laboratory, 303-384-7557, chandra_shah@nrel.gov

[11] http://www.arnet.gov/far/current/html/Subpart_17_5.html

3. COMMERCIAL AND INDUSTRIAL BOILERS IN THE FRONT RANGE

One affordable alternative to building a new biomass energy facility is to find an existing solid-fuel, gas or oil boiler and either convert it to use biomass or co0fire the biomass with fossil fuel.. The purpose of this effort was to identify facilities that could potentially utilize biomass energy technology in an existing boiler.

The search effort focused on the following types of facilities:

- Power plants and cement plants that could be sites for biomass cofiring with coal or coke for power or thermal applications;
- Large commercial and industrial boiler systems as potential candidates for biomass heating and/or power generation; and
- Small- to mid-size commercial facilities as potential sites for biomass heating or small modular biomass power applications.

The facility locations and other information were entered into a geographic information systems (GIS) database to show where they are located relative to the biomass resource.

The information provided is not suitable for recommending individual facilities as candidate sites for biomass energy technology. Rather, the results of this task provide the basis for stakeholders to take the next steps, including contacting facility managers to discuss potential opportunities. This step might be taken by county and local government, state and federal land managers, entrepreneurs or a regional coalition of all of these groups.

Two facilities in Colorado are already co-firing biomass and coal. These are described in Section 3.2. Two additional facilities (the Nederland Community Center and Boulder County's new office complex in Longmont) will be using biomass to heat their buildings.

3.1 Data Sources and Analytical Approach

The U.S. EPA E-Grid (Emissions and Generation Resource Integrated Database) provided the locations, size, fuel type and other information on utility and non-utility power plants in the study area.[12] A search of the U.S. EPA Air Data facility database[13] by Standard Industrial Classification, or SIC, codes 3271 to 3275 provided the location of cement plants.

The U.S. EPA Air Data National Toxics Inventory (NTI) database provided information on location and facility type for large commercial and industrial boiler systems. The NTI Database provided information on all major stationary emissions sources. A major source is defined as a stationary (point) source that emits, or has the potential to emit, 10 tons or more per year of any listed hazardous air pollutant (HAP) or 25 tons or more per year of a combination of listed

[12] U.S. EPA E-Grid 98. On-line at: http://www.epa.gov/cleanenergy/egrid/index.html.
[13] U.S. EPA Air Data Facility Database. On-line at: http://www.epa.gov/air/data/info.html.

HAPs.[14] The NTI Database did not distinguish between energy-related and other sources of emissions. However, it was possible to determine which permitted facilities had emissions related to combustion sources by selecting facilities that emit carbon monoxide, a byproduct of combustion. The benefit of the NTI Database was that it provided location (latitude and longitude coordinates) and SIC codes for each point source. Information on fuel type is not available from state and federal databases of boilers and other combustion sources; information on energy use and cost is equally difficult to obtain.

For smaller-scale biomass heating applications, a larger variety of types and sizes of facilities may be potential candidates than the U.S. EPA Air Data databases describe. Such facilities can include, but are not limited to, schools, hospitals, correctional facilities, government buildings and commercial and industrial facilities. The Colorado Boiler Database includes a wider range of facilities than the NTI database, because it includes all boilers subject to inspection by the Colorado Department of Labor and Employment. The Colorado Boiler Database provides additional details such as contact information, boiler type and boiler capacity for facilities with boilers.[15] It also allows users to find contact information for facilities. The on-line version of the Colorado Boiler Database does not allow users to generate reports that provide information on large numbers of facilities, but it does allow users to search for facilities by location. Therefore, while boilers for smaller commercial boiler systems were not included in the GIS overlays, this data source is recommended as a potential source of more detailed information when more detailed facility information is desired.

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[14] U.S. EPA Air Data NTI Database. On-line: http://www.epa.gov/air/data/ntidb.html Accessed September 25, 2003.

[15] Colorado Department of Labor and Employment, Division of Oil and Public Safety. Colorado Boiler Database: On-line: http://oil.cdle.state.co.us/Boiler/Boiler Database/boiler database home.asp. Accessed September 25, 2003.

3.2 Type and Locations of Commercial and Industrial Boiler Systems

Table 3-1 shows the 9 coal power plants in the Front Range, which have a combined nameplate power generation capacity of 2,789 total megawatts (MW). There is an additional 218 MW of natural gas-fired capacity. Hydroelectric power (not shown in Table 3-1 because hydroelectric plants are not candidate sites for a biomass power plant) makes up an additional 705.3 MW of capacity. Appendix C provides additional details about these non-hydro facilities.

Table 3-1. Non-hydroelectric power plants in Front Range, by primary fuel type

	Coal		Natural gas		Total	
County	Number of plants	Capacity	Number of plants	Capacity	Number of plants	Capacity
Boulder	1	211	1	33	2	244
Denver	2	963	1	101	3	1,064
El Paso	2	596	1	59	3	655
Fremont	1	39	-		1	39
Jefferson	1	35	-		1	35
Larimer	1	285	-		1	285
Pueblo	1	660	1	25	2	685
Total	9	2,789	4	218	13	3,007

Source: U.S. EPA E-Grid 2000. On-line at: http://www.epa.gov/cleanenergy/egrid/index.html.

Coal makes up 75 percent of total generation capacity (including hydro), hydroelectric 19 percent and natural gas 6 percent. Wind energy makes up a very minor part of total generation in Colorado.

3.2.1 Utility Biomass Cofiring Experience in Colorado

Cofiring wood with coal has been the subject of numerous demonstration projects around the U.S., including a few in Colorado. The W.N. Clark Power Plant, in Cañon City (owned by Aquila Inc., an investor-owned utility serving portions of southern Colorado) test fired 1-2 percent wood in a pulverized coal station during 2001 and 2002. The W.N. Clark Power Plant has two coal-fired generating units with a combined generating capacity of 42 megawatts (MW). The boiler systems are Detroit Stoker traveling grate stokers. The plant burns 363 to 454 metric tons (400 to 500 short tons) of coal per day, and is permitted to burn up to 5 percent wood (as a proportion of total fuel weight), or 18 to 23 metric tons (20 to 25 short tons) of wood per day. The boiler system is designed to burn fine particles 0.6 cm (¼ inch) in diameter, but can handle smaller quantities of particles up to 5 cm (2 inches) in diameter.

The plant test fired approximately 1 percent, or approximately 1.8 to 3.6 green metric tons (2 to 4 green short tons per day) wood on a nearly continuous basis from September, 2001 through the summer of 2002. Some of the wood was from fuelwood reduction activities on the Bar NI Ranch. The majority of the fuel used was ponderosa pine. The approximate heating value for ponderosa pine is 21.12 megajoules per dry kilogram (9,100 Btu per dry pound) for wood and 21.8 megajoules per dry kilogram (9,400 Btu per dry pound) for bark. The moisture content of the fuel as received varies from 50 to 60 percent. Attempts to burn cottonwood from local arborists were problematic because the cottonwood was stringy and would clog the fuel delivery system. The wood fuel is fed on top of the coal in rail cars. The wood fuel blends with the coal when the fuel is dumped through the car bottom.

Current fuel handling systems at the plant can only support approximately 1 to 2 percent co-firing, or 3.6 to 4.5 green metric tons (4 to 5 short tons) per day. If the plant were to ramp up to 5 percent wood, investment in a new fuel receiving and handling system would be necessary. The approximate cost for such a system would be several hundred thousand dollars. In addition, the plant would have to increase their wood fuel storage capacity from about 22 metric tons (24 short tons) to about 135 to 180 metric tons (150 to 200 short tons).

In the Fall of 2003, Aquila will conduct a new project related to biomass cofiring. The goal of the study will be to develop a forest health and biomass power "green tags" program. Additional information on the concept of green tags can be found in Section 5.1.4 of this report. Aquila will cofire forest biomass and coal at their W.N. Clark Power Plant in Canon City, Colorado.

The idea is to sell green tags from the biomass portion of the electricity generated through cofiring to residents, businesses and government agencies to help offset the additional cost of biomass when compared to coal. Green tags can be sold to anyone and are not limited by geography or utility service territory. If this project is successful, it will be the first of its kind in the country.

Cofiring biomass and coal is currently the most cost-effective option for converting biomass to electricity. The plant where Aquila plans to burn biomass is already permitted for wood.

This project will help overcome a number of economic and other barriers that biomass power generation faces:

- Biomass fuel costs more than coal on a dollar per million Btu basis and for cofiring, requires utility capital investment for handling;

- Third-party green energy certification programs do not currently recognize forest biomass as an eligible renewable resource for the sale of green tags or green power; and

- There is a lack of understanding between many citizen and environmental groups regarding the difference between biomass from forest stewardship activities and that from unsustainable forestry practices.

To market and sell green tags from the power, project partners will perform the following: identify and meet regulatory and green power certification requirements; work with certification programs to negotiate certification of forest biomass; develop a green tag pricing policy for the power provider; conceive and implement a business model for selling green tags to consumers; develop a marketing plan and materials for the program; implement the green tags program; and document the program results.

Colorado Springs Utilities is proceeding with plans to build a new fluidized bed power plant near Colorado Springs. The utility is interested in exploring the possibility of including biomass in its supply mix for this plant. This project is still a few years from coming on line, but it could potentially serve as a major outlet for biomass from the Front Range.

McNeil staff spoke to Xcel Energy about the potential to cofire coal and biomass at some of its plants along the Front Range. Xcel stated that it has recently converted several units at some of its plants to natural gas. Xcel also just updated the emissions controls at several metro area plants, and it is reluctant to do anything that would cause a modification of its air permits.

3.2.2 Cofiring Potential at Colorado Cement Plants

Cement plants are potentially viable sites for co-firing wood with coal or coke in cement kilns. In this combustion process, the fuel actually becomes chemically incorporated into the clinker, an intermediate product in the manufacturing of cement. In the Front Range, the NTI Database identified three hydraulic cement plants in or near the study area:

- Southwestern Portland Cement, 5134 Ute Hwy Lyons, CO 80540, Boulder County,
- Holcim Inc. (formerly Holnam, Inc.) Portland Plant, 3500 Hwy 120 Florence, CO 81226, Fremont County and
- Holcim Inc. (formerly Holnam, Inc.), 4629 N Overland Trail LaPorte, CO 80535, Larimer County.

Testing of wood/coal co-firing at an industrial cement kiln at Holcim (US) Inc. in LaPorte, Colorado showed that up to 350 tons per day coal consumption could be replaced by wood (with a likely optimal 75 to 100 ton per day wood content for normal operation). Though this plant location has closed[16], work is being done, with assistance from the Colorado State University Department of Forest Sciences, to explore additional testing. This testing will occur at the Holcim (US) Inc. Portland Plant in Florence, Colorado and the Southdown Portland Plant in Lyons, Colorado. While there are no commitments to pursuing co-firing at these plants, there are significant opportunities at these and other industrial kiln operations for project development, provided adequate pre-feasibility work and testing is performed. There are also concrete plants in the study area, but these companies do not necessarily have kilns. However, some may have

[16] U.S. Geological Survey. The Minerals Industry of Colorado 2002. On-line: http://minerals.usgs.gov/minerals/pubs/state/2002/costmyb02.pdf

significant heating loads. Appendix C contains contact information for several of the concrete plants in the study area, taken from the U.S. EPA Air Data facility database.

A query of the NTI Database for the study area identified 261 major stationary combustion sources in the region. Figure 3-1 shows the location of 181 of these sites, excluding those that represent less than 1 percent of estimated total carbon monoxide emissions from stationary sources in the region. The remaining facilities were not included in the map so that the level of clarity of the map could be improved. These 181 facilities represent 99 percent of the total emissions from the 261 facilities. The greatest number of facilities is concentrated in metropolitan areas, which makes it difficult to distinguish between point sources in the figure. . Figure 3-1 also shows the power plants from Table 3-1. Appendix D provides a list of all of these stationary sources.

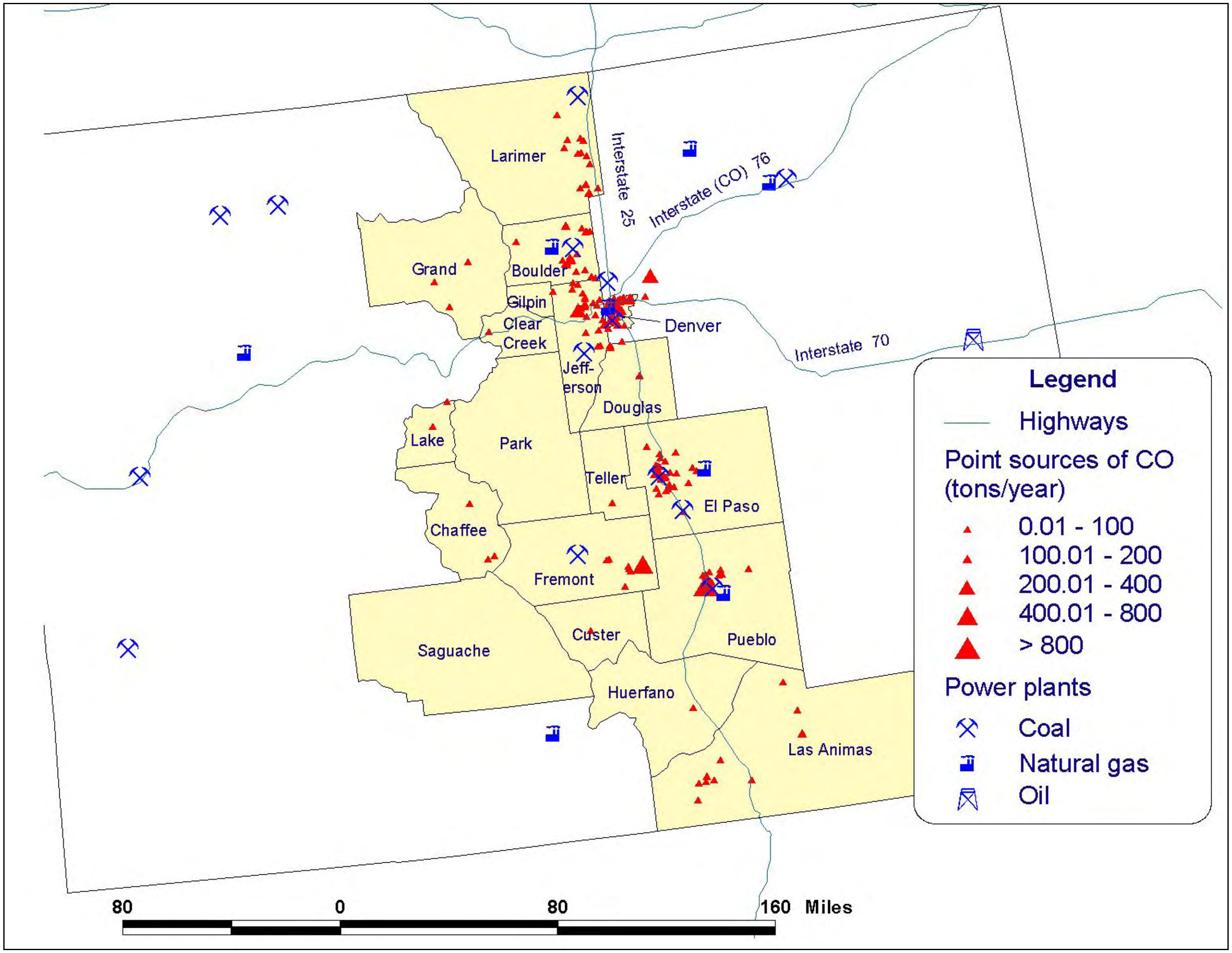


Figure 3-1. Locations of power plants and commercial and industrial combustion sources

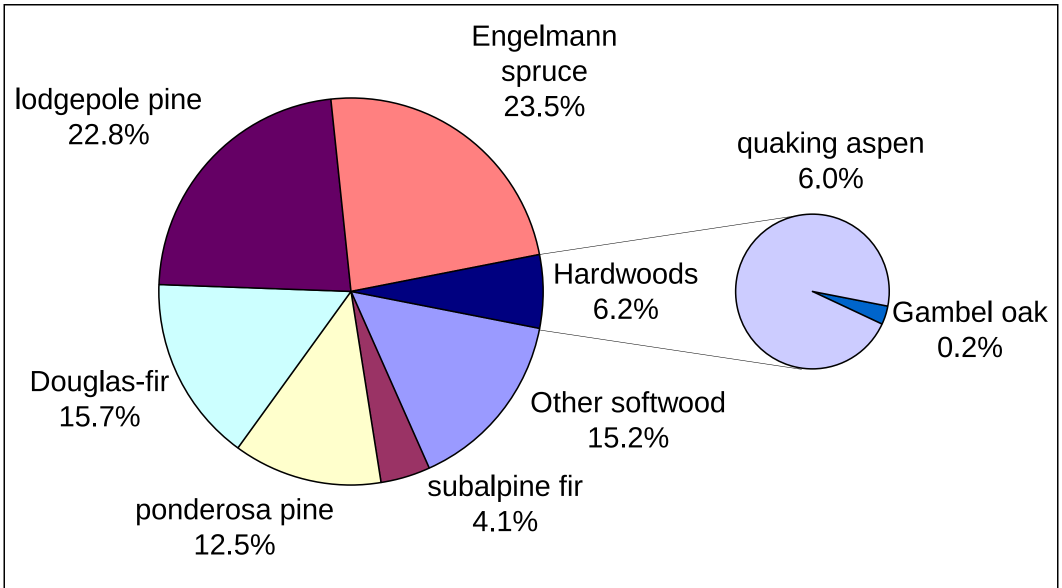
4. BIOMASS RESOURCE ASSESSMENT

This resource assessment evaluates biomass generation and availability from forestry (including timber stand improvement and forest thinning designed to reduce wildfire risks) and urban wood residues such as wood products residues, yards and gardens, tree trimming and building. The estimates in this section include values updated from a previous study performed by the Front Range Forest Health Partnership.[17]

4.1 Forest Biomass

4.1.1 Resource Overview

Biomass from forest management in the area is dominated by softwood (evergreen) tree species. Figure 4-1 shows the species composition of live tree volume on forest land with slopes less than 30 percent for counties within the Front Range of Colorado, as defined for this study. Four softwood tree species (Engelmann spruce, lodgepole pine, Douglas-fir and ponderosa pine) make up 75 percent of the live tree volume on forest land. Hardwood species make up only 6.2 percent of the total live volume.



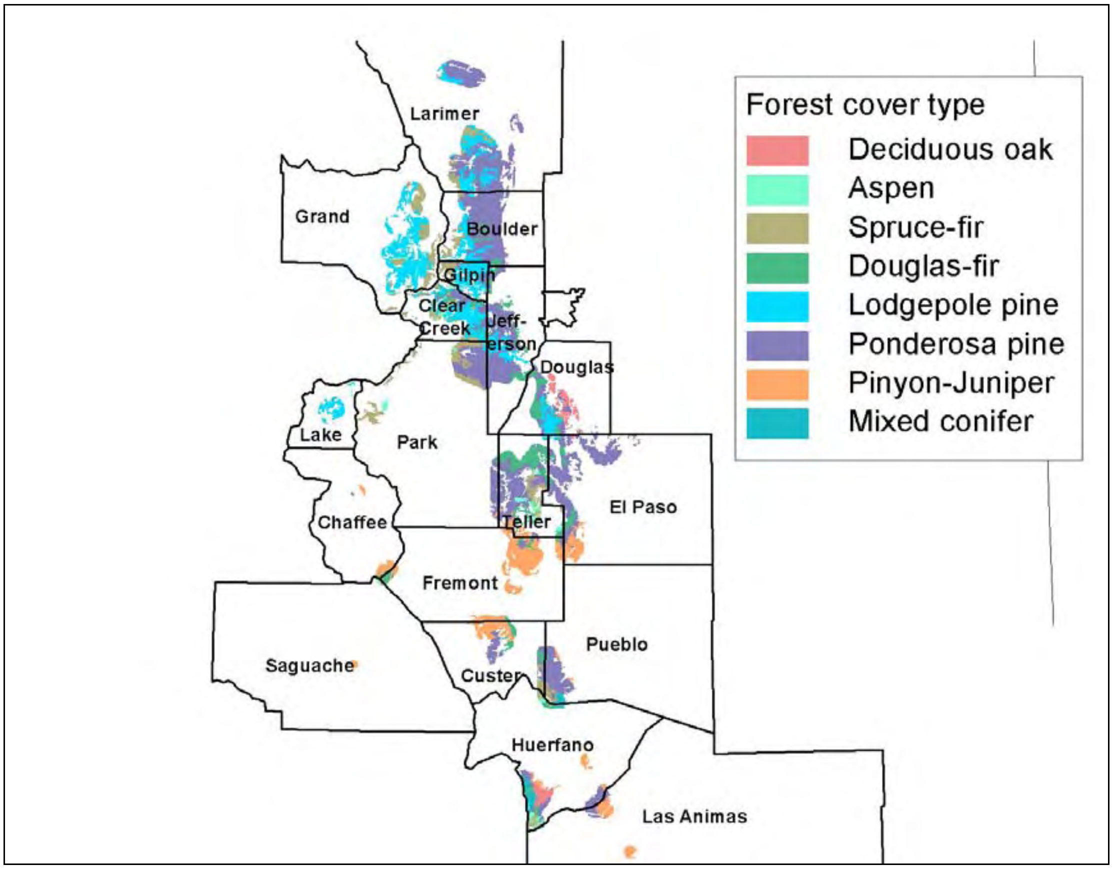
Other softwood includes: blue spruce (2.1%), rocky mountain juniper (2.2%), oneseed juniper (1%), Utah juniper (0.5%), bristlecone pine (2.5%), common pinyon (3.2%), limber pine (3.2%), white fir (0.5%), and corkbark fir (0.1%)

Source: USFS Forest Inventory and Analysis. MOIMS Forest Inventory Mapmaker Version 1.0. Colorado 2002 inventory cycle 2. Covers Front Range counties

[17] Coloradans for Clean Air. Colorado Front Range Wood Resource Assessment. April 1997. Prepared by NEOS Corporation under contract to the Front Range Forest Health Partnership.

Figure 4-1. Species composition of live tree volume for forest land with slopes less than or equal to 30 percent in the Colorado Front Range

The Red Zone delineates urban and suburban areas that are at risk of wildfire. The CSFS developed the Red Zone map for Colorado using housing density, slope, aspect and fuels information integrated into a GIS system along with the USFS, BLM, NPS and other stakeholders. Ponderosa pine forest covers the largest percent area of any forest type, although it represents a smaller percentage of the live tree volume (see Figure 4-1). The Red Zone portion of the Front Range is heavily forested (70 percent of land area) compared to other areas of the state.

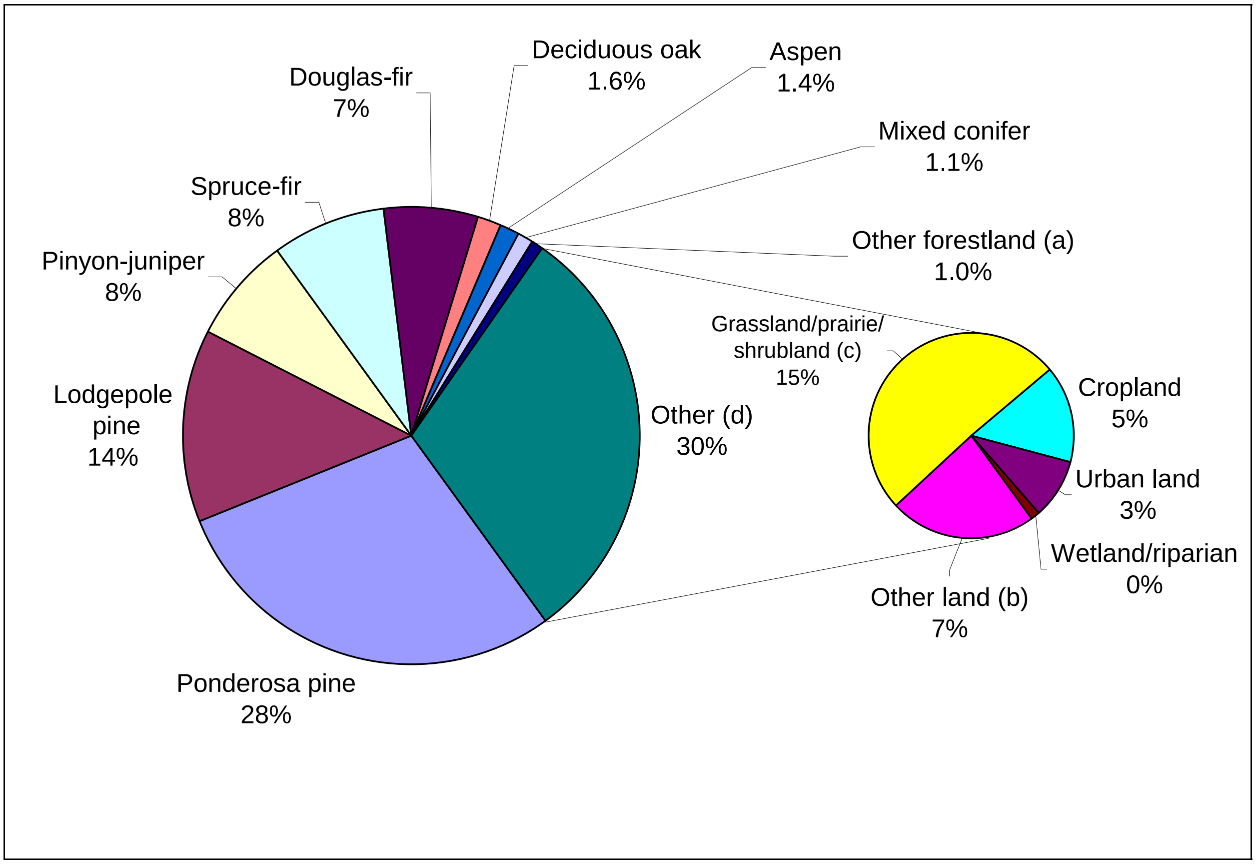


Source: Vegetation layer provided by Natural Diversity Information Source, a joint mapping effort by the Colorado Department of Natural Resources, Colorado Division of Wildlife, Colorado Natural Heritage Program and Colorado State University. (http://ndis.nrel.colostate.edu).

Figure 4-2. Forest cover types within the "Red Zone" in Front Range counties

These data are appropriate for coarse-scale analysis and planning only. They are not appropriate for site-specific analysis and indicate only the primary vegetation cover type in the area.

Figure 4-3 summarizes land cover patterns within the Red Zone area in Front Range counties. Major non-forest land cover types include grassland/prairie/shrubland, cropland and urban areas.



Source: Vegetation layer provided by Natural Diversity Information Source, a joint mapping effort by the Colorado Department of Natural Resources, Colorado Division of Wildlife, Colorado Natural Heritage Program and Colorado State University. (http://ndis.nrel.colostate.edu). Overlaid with Red Zone map boundary provided by Edel, Skip, GIS Coordinator, CSFS.

(a) Lodgepole clearcut, limber pine, mixed forest, pure spruce, white fir, Rocky Mountain bristlecone pine

(b) Forest, grass/forb and shrub dominated wetland/riparian

(c) Big sagebrush, desert shrub, foothills and mountain grassland, greasewood fans and flats, xeric/mesic upland shrublands, shortgrass/mid-grass/tall grass prairie

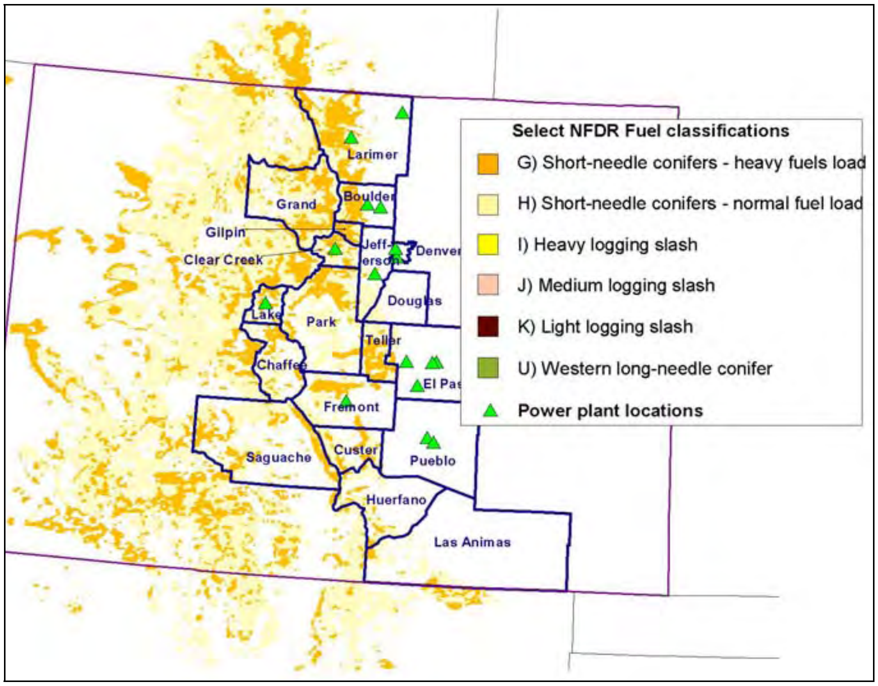
(d) Bare ground tundra, meadow tundra, mixed tundra, prostrate shrub and tundra, subalpine meadow, barren land, exposed rock, mining operations

Figure 4-3. Percent land cover in Red Zone portion of Colorado's Front Range

In addition to the Red Zone map, we consulted several additional data sources to show broad-level geographic distribution of fuel loads in the Front Range.

The U.S. Forest Service developed the National Fuel Danger Rating System (NFDRS) as a means of integrating vegetation information, topographic information, and other factors in to a

GIS analytical tool to show potential fire risks, as an aide to land managers and fire fighters.[18] The NFDRS was derived from previously mapped land cover classes, satellite imagery, extensive ground sampling data and field verification by regional fire managers.[19] NOAA provides more documentation of the structure of the NFDRS at its website.[20] The NFDRS has been used in a variety of experimental fuel modeling efforts to forecast fire conditions at various sites.[21] One of the key inputs to the NFDRS is the Fuel Model Map, which classifies fuel loading types and extent. Figure 4-4 shows that the primary fuel load types in the Front Range include short-needle conifers, though the coarse (one kilometer) resolution of the fuel model does not reveal other fuel types that exist in the area, including logging slash and long-needle conifer.



Source: USFS Wildland Fire Assessment System – National Fuel Danger Rating System. On-line: http://www.fs.fed.us/land/wfas/nfdr_map.htm

Figure 4-4, Fuel load map for Front Range counties

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[18]USFS Wildland Fire Assessment System – National Fuel Danger Rating System. On-line: http://www.fs.fed.us/land/wfas/nfdr_map.htm

[19] Burgan, Robert E. (USFS – retired), Robert W. Klaver and Jacqueline M. Klaver. (USGS EROS Data Center). May 10, 2000. Fuel Models and Fire Potential from Satellite and Surface Observations. On-line: http://www.fs.fed.us/land/wfas/firepot/fpipap.htm

[20] NOAA. National Fire Danger Rating System Model Description. On-line: http://www.seawfo.noaa.gov/fire/olm/nfdrs.htm

[21] NOAA. Experimental NFDRS Forecasts – Missoula, MT. On-line: http://www.wrh.noaa.gov/cgi-bin/Missoula/msonfdrsmain

4.1.2 Data Sources and Analytical Approach

The approach to estimating forest biomass generation several steps:

- Updating forest land resource and biomass yield data for the Front Range;
- Estimating total resource potential using methods developed for a study conducted for the Front Range Forest Health Partnership;
- Conducting phone interviews with CSFS and U.S. Forest Service district rangers and county land management agencies and other land management officials to collect information on planned treatment acreage, treatment type, and yield;
- Estimating potential and current biomass generation using the information collected; and
- Integrating results into a GIS system showing biomass generation and availability.

The Front Range Forest Health Partnership study focused on the potential to develop a bioethanol facility in the Front Range. Its findings included that the regional resource was sufficient, but technology readiness and feedstock costs prevented moving forward with a facility at that time. This study used an analogous method to determine total resource potential in the Front Range of Colorado by manipulating land resource and biomass yield data.

Land resource: Coarse-scale (1:100,000) vegetation, land cover and land ownership geographic data are available through the Natural Diversity Information Source, a joint mapping effort by the Colorado Department of Natural Resources, Colorado Division of Wildlife, Colorado Natural Heritage Program and Colorado State University.[22] We used these data in conjunction with the Red Zone data to obtain estimates of primary vegetation cover types on forested land with in Red Zone areas in Front Range counties.

Biomass yield: Biomass yield assumptions used to estimate biomass potential within the Red Zone portions of the Front Range are specific to forest stocking levels in each county. USFS Forest Inventory & Analysis Database (FIADB) volume data was used to determine volume of material for diameter classes less than 11 inches diameter at breast height (dbh) in each county. Where data were not available, average volume was assumed.[23] This yield method takes into account differences in regional forest fuels loading, unlike the prior Front Range study which used a uniform yield factor of 19.7 GT per acre, based on time, motion and yield studies in the San Juan National Forest.[24]

To estimate potential annual biomass generation, it is assumed that five percent of the forested area in the Red Zone portion of Front Range counties will be managed each year. Total forested acres within each county was multiplied by the percentage of forest land with slopes less than 40 percent and by the assumed yield for each county to estimate annual biomass generation. To take into account the need to maintain some biomass on-site, it was assumed that five GT per acre

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[22] Natural Diversity Information Source. On-line: http://ndis.nrel.colostate.edu

[23] USFS FIADB Colorado 2002 Cycle 2 data. On-line: http://www.fia.fs.fed.us

24 Lynch, D. L., and Jones, C.S., Summary Report, Timber Harvesting Study for Unit 1 - “Smoothing Iron” Ecosystem Restoration Project, Department of Forest Sciences, Colorado State University, April 1996.

would be unavailable. This is consistent with fuel manager practices in the western U.S., although site-specific conditions might dictate more or less fuel remain on site.[25]

Current biomass generation: USFS National Fire Plan on-line project databases and interviews with land management personnel provided fuels reduction project information. Biomass quantities were estimated from treatment acreage assuming 11 GT per acre, average biomass generation based on fuels loading in the region.

4.1.3 Forest Biomass Generation

Forest biomass potential: Table 4-1 provides estimates of biomass potential from the more than two million acres of forest land in the Red Zone portion of the Front Range, assuming all the forest land is managed on a 20 year cycle. Forest biomass quantities are reported in GT.

Table 4-1. County-level forest biomass generation potential, if 5 percent of forestland with slopes less than 40 percent in Red Zone is managed annually

County	Percent Forest land under 40% slope	Biomass yield (GT/acre)	Total forested acres	Total forested acres with slope <40%	Total acres managed/ year	Total forest biomass available (GT/year)
Boulder	43%	11	216,000	92,572	4,629	50,046
Chaffee	78%	4	15,009	11,654	583	2,199
Clear Creek	0%	11	140,836	-	-	-
Custer	46%	11	82,835	38,192	1,910	20,648
Douglas	66%	9	115,428	75,717	3,786	33,516
El Paso	65%	11	181,562	118,015	5,901	63,801
Fremont	70%	11	126,783	88,429	4,421	47,806
Gilpin	67%	15	79,721	53,148	2,657	39,216
Grand	68%	28	190,861	130,470	6,523	180,547
Huerfano	78%	17	106,958	83,232	4,162	71,660
Jefferson	47%	11	173,819	81,115	4,056	43,853
Lake	69%	25	22,493	15,531	777	19,327
Larimer	73%	5	255,214	185,376	9,269	48,262
Las Animas	86%	4	35,015	29,938	1,497	6,190
Park	78%	5	163,161	127,314	6,366	31,047
Pueblo	50%	11	71,982	35,991	1,800	19,457
Saguache	80%	7	5,786	4,629	231	1,656
Teller	56%	3	209,114	116,174	5,809	19,528
Total			2,192,577	1,287,496	64,375	698,759

[25] Rockwell, Victoria, Forest Silviculturalist, USFS Wallowa-Whitman National Forest. Personal communication with Tim Rooney, McNeil Technologies, Inc., July 23, 2003.

All forest land is not necessarily going to be treated to reduce fuels. That is why this effort focused on forested areas with relatively gentle slopes. Over the course of several decades, some areas will be treated more than once to further reduce fuels.

Current biomass generation: The quantity of biomass generated by current management intensity on federal, state, local government and private land is less than the potential if the majority of the forest land in the Red Zone with relatively gentle slopes was managed. Forest land management agencies focus on high-priority treatment areas and given budgetary constraints. An interagency partnership called the Front Range Fuels Treatment Partnership (FRFTP) has undergone a hazard mapping process for Arapahoe & Roosevelt National Forests (ARP) and Pike & San Isabel National Forests (PSICC). The results of the assessment have indicated that approximately 510,000 acres are high priority for treatment. There are 300,000 acres within the PSICC, 140,000 acres within the ARP and 70,000 acres of non-federal lands.

The FRFTP developed a multiyear strategy for treating fuels on USFS land in the Front Range, showing acres to be treated within high-priority treatment areas. Table 4-2 shows past mechanical treatment acreage for USFS land in the Colorado Front Range for 2001 and current and projected fuels treatment acreage based on the FRFTP strategy. Appendix E provides more information on prospective funding and planning efforts in the area.

Table 4-2. Past, current and projected mechanical treatment on USFS land

Forest	Year	Treatment – mechanical (acres)	Biomass generation (GT/year)
Arapaho & Roosevelt	2001	300	3,244
Pike & San Isabel	2001	1,285	13,894
Rio Grande	2001	-	-
2001 Total		**1,585**	**17,138**
Arapaho & Roosevelt	2002	229	2,473
Pike & San Isabel	2002	790	8,542
Rio Grande	2002	-	-
2002 Total		**1,019**	**11,015**
Arapaho & Roosevelt	2003	1,682	18,186
Pike & San Isabel	2003	520	5,622
Rio Grande	2003	-	-
2003 Total		**2,202**	**23,809**
Arapaho & Roosevelt	2004	818	8,839
Pike & San Isabel	2004	3,450	37,303
Rio Grande	2004	-	-
2004 Total		**4,268**	**46,142**
Arapaho & Roosevelt	2005-2012	1,680	18,165
Pike & San Isabel	2005-2012	4,500	48,656
Rio Grande	2005-2012	-	-
2005 Total		**6,180**	**66,821**

Note: Mechanical treatment plans from FRFTP 2003 Plan were estimated at 15 percent of total acreage treated, based on prior years performance. Sources: 2001 – 2002: USGS Hazardous Fuels Reduction Map Viewer. Formerly on-line, no longer active; 2003 - 2005: FRFTP. January 2003. Strategy to Reduce Wildland Fire Risks Through Sustained Fuels Treatment along the Colorado Front Range.

Planned fuels treatment acreage data do not break out prescribed fire vs. mechanical treatment, so planned mechanical treatment acreage was estimated assuming it will represent 15 percent of the total area treated. This is consistent with past treatment acreage.

A survey of county land management agencies provided information about mechanical treatment by local government agencies, in addition to USFS land. Table 4-3 provides the professional opinion of county and CSFS personnel regarding fire risks, treatment needs, and past mechanical treatment levels by local and county government for counties within the Front Range. Appendix F provides the detailed results of these contacts. In addition, Table 4-3 shows that an estimated 15,440 GT of biomass is generated through local fuels treatment activities, assuming 11 GT per acre yields. Most of the material is unutilized, with the exception of Grand County, which produces 2,500 cords (approximately 1,250 tons) of firewood each year through its CSFS programs. Several other counties also use small amounts of the material generated for firewood.

Table 4-3. Estimated county-level wildfire risks and local government treatment as reported by county fuels personnel

County	Acres at high risk of wildfire	Acres in need of treatment	Acres mechanically thinned per year past 5 years average	Annual biomass generation from past 5 years treatment (GT)
Boulder	-	11,000	100	1,081
Chaffee	27,000	36,117	150	1,622
Clear Creek	3,465	2,000	-	-
Grand	15,000	10,000	200	2,162
Huerfano	67,000	71,000	130	1,406
Lake	18,000	24,994	15	162
Larimer	-	-	-	-
Las Animas	300,000	466,000	833	9,007
Pueblo	-	-	-	-
Teller	-	700	-	-
Total	430,465	621,811	1,428	15,440

Note: Data were not provided for Custer, Douglas, El Paso, Fremont, Gilpin, Jefferson, Park and Saguache counties

Private landowners also generate biomass through fuels reduction efforts on their own land, though fuels reduction and a variety of other management activities. However there is no data source that tracks fuels reduction on private land. The CSFS does help landowners develop management plans for private forest landowners. For purposes of this study, the conservative assumption that some form of forest management occurs on two percent of private land was made to facilitate estimation of biomass generation. Multiplying estimated private forest land acreage under 40 percent slope by this assumed management intensity provided an estimate of annual treatment acreage. Multiplying annual treatment acreage by the yield assumption of 11 GT per acre per year provided estimated annual biomass generation, shown in Table 4-4.

Table 4-4. Estimated biomass quantity generated from fuels reduction on private land

County	Total forested acres	Percent forest land under 40% slope	Estimated forested acres under 40% slope	Estimated acres treated/year	Estimated biomass generation (GT/year)
Chaffee	58,640	77.6%	45,533	911	9,846
Custer	58,640	46.1%	27,037	541	5,847
Douglas	20,367	65.6%	13,360	267	2,889
El Paso	114,358	65.0%	74,333	1,487	16,074
Grand	57,873	68.4%	39,561	791	8,555
Gunnison	57,873	72.2%	41,784	836	9,036
Jefferson	42,884	46.7%	20,013	400	4,328
Lake	57,179	69.0%	39,480	790	8,537
Larimer	100,063	72.6%	72,681	1,454	15,717
Las Animas	117,280	85.5%	100,275	2,006	21,684
Park	354,859	78.0%	276,894	5,538	59,878
Teller	28,590	55.6%	15,883	318	3,435
Total	1,010,733	Not applicable	725,050	14,501	156,791

Source for forest acreage and slope: USFS FIADB. Colorado 2002 Cycle 2. No data available for private land data for Boulder, Clear Creek, Denver, Fremont, Gilpin, Huerfano, Pueblo and Saguache Counties.

Table 4-5 summarizes forest biomass generation based on current management levels. Approximately 218,373 GT of forest biomass are currently generated from forest management in the region, or 31 percent of that which could be generated if all the forest land with slopes less than 40 percent in the Red Zone portions of Front Range counties.

Table 4-5. Estimated current annual forest biomass generation (GT/year)

County	County/local	Private land	Federal (based on 2004 projects)
Boulder	1,081	ND	Arapaho & Roosevelt NF:
Chaffee	1,622	9,846	8,839
Custer	-	5,847	Pike & San Isabel NF:
Douglas	-	2,889	37,303
El Paso	-	16,074	Rio Grande NF
Grand	2,162	8,555	-
Huerfano	1,406	ND	
Jefferson	-	4,328	
Lake	162	8,537	
Larimer	-	15,717	
Las Animas	9,007	21,684	
Park	-	59,878	
Teller	-	3,435	
Subtotal	15,440	156,791	46,142
		Total	**218,373**

Note: No data (ND) were available for private or county/local management in Clear Creek, Fremont, Gilpin, Pueblo and Saguache counties.

4.1.4 Forest Biomass Availability and Cost

Estimates of biomass generation took into account slope limitations on forest management and, to the extent possible, accounted for land manager preferences by only assuming a limited land area would be managed in any given year. However, one key issue associated with biomass delivery systems is cost. Table 4-6 provides estimates of average roadside forest biomass costs based on time and motion studies for operations in the western U.S. Costs will vary according to site-specific conditions.

Table 4-6. Range of roadside chipped forest biomass costs and yields

Project	Roadside chip cost ($/GT)[a]
Ponderosa Pine Partnership[26]	
Unit 1	41.76
Unit 4	46.41
Unit 5b	39.06
Unit 5e	29.80
Wyoming time and motion studies[27]	
Wyoming- Neuson[a]	41.68
Wyoming- Manual[a]	30.88
Average	38.26

[a] Chipping costs were assumed to be $ 6.39 per green ton, based on a 1997 WRBEP time and motion study of chipping operations. [28] Chipping cost estimates were escalated from 1997 values to 2003 using an assumed 2 percent inflation rate.
[b] Wyoming study biomass yields not available because source was a time and motion study conducted on 0.1 acre plots, and estimation of per acre volume are not feasible.

Transportation costs are largely a function of distance. Trucking companies often charge by loaded mile. Some companies offer a graduated rate system, in which the rate per loaded mile is the same within a "donut" that represents a particular transport distance from the starting point, but changes as the hauling distance increases. Trucking costs decrease per ton-mile when larger chip vans are used. Live-bottom trailers or chip vans that carry 20 to 25 GT of chips are often used for biomass power plants. Forest biomass trucking costs are similar to that for agricultural residues, which range from $6.20 to $14.20 for distances ranging from 10 to 100 miles,

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[26] Lynch, D.L., and K.H. Mackes. 2002. Evaluating Costs Associated with Fuel Hazard Reduction and Forest Restoration Projects in Colorado. Department of Forest Sciences, Colorado State University, Fort Collins, CO.

[27] Klepac, J.F., and R.B. Rummer.2002. Smallwood Logging Production and Costs: Mechanized vs. Manual. ASAE International Meeting July 28-31 2002, Chicago, Illinois. Paper Number 025007

[28] WRBEP. Evaluation of Biomass Utilization Options in the Lake Tahoe Basin. Prepared by NEOS Corporation. September 1997.

respectively according to a recent study of costs for agricultural residue hauling in Colusa County, California.[29]

The delivered cost of biomass ranges from as little as $36 per green ton for forest biomass harvested mechanically from stands with a low slope and transported 10 miles to as much as $56 for biomass harvested from high-slope stands hauled 100 miles. This assumes that all costs of harvesting, chipping or grinding and transportation are attributed to the price of biomass feedstocks. In most cases, biomass feedstocks come from more easily accessible forest stands located at most 50 to 75 miles from the point of use.

In many cases, biomass energy facilities do not pay for the entire cost of collecting and transporting biomass to the energy facility, nor could they and remain cost effective in many current power markets. The allocation of costs for biomass sold to a bioenergy facility is often determined through negotiations with specific forestry professionals. Logging debris treatment is a means of controlling soil erosion and preventing soil disturbance. Debris generated over and above the amount needed to serve these functions is often simply an aesthetic problem and can contribute to forest fire risks. In some cases the land owner or forester will be interested in selling biomass as a way to reduce accumulated biomass and defray pile burning or other debris disposal costs. The USFS should consider diverting some of the funds used for pile burning debris to helping pay for biomass removal and chipping costs.

A biomass power plant can often obtain forest biomass for only the costs of collection, chipping and transportation. In fact, many biomass power plants currently pay anywhere from $5.00 to $25.00 for biomass fuel. A significant concern for biomass costs, however, is the existence of competing markets. If an existing market for forest biomass exists, then building an additional plant in the area will boost biomass prices for both plants, since the supply of biomass is often determined by land-owner preference for forest management and timber commodity prices, rather than by demand for biomass fuel.

4.2 Urban Wood Residues

Another significant source of wood biomass is from urban sources. Biomass from urban wood resources is a relatively stable source of supply since it is generated from construction, urban tree maintenance, landscaping and other sources that are dependent more on population than on forest resource availability. Much urban wood residue can be obtained at a relatively low cost. A facility may even be paid to take the material if the generator is currently paying to dispose of the material. A greater degree of care must be taken to obtain clean, i.e., unpainted, untreated, wood biomass from urban sources than for forest biomass. However, urban biomass can play a part in making a reliable fuel supply with a lower blended average cost than forest biomass alone.

[29] Rice Straw Feedstock Joint Venture, Rice Straw Feedstock Supply Study for Colusa County California, Western Regional Biomass Energy Program, Lincoln, NE, 1999

4.2.1 Resource Overview

In order to estimate potential annual wood fuel supplies from urban sources, we evaluated biomass generation and availability from urban tree residues (UTR), wood products residues and construction and demolition wastes.

UTR consists of wood residues from lawns and gardens, municipal and commercial tree care firms, utility line maintenance, landscaping, excavation and land clearing. UTR consists mainly of ornamental native and non-native trees and shrubs.

Urban forestry residues are a heterogeneous feedstock; they may be in the form of tops, branches, stumps, chips, whole trees or logs. Often they are in a mixture of forms. They are also often dispersed across many properties, although many counties operate wood recycling centers or offer drop-off centers for wood waste. Some landfills also operate wood separation programs, in which clean wood is separated from MSW.

Wood products residues include wood byproducts of pallet and wood products manufacturing. Primary wood processors include establishments that use raw, unprocessed logs or other roundwood as part of their raw material (e.g., sawmills). Secondary wood processors use raw material that has already undergone one or more processing steps (i.e., flooring or furniture manufacturers). This effort focused on clean, unpainted, untreated biomass materials.

There are many, many tree species used for wood product manufacturing. Table 4-7 summarizes the quantity of wood products consumed in Colorado and the tree species used in the production of those goods. The predominant tree species used in wood products manufactured in Colorado include Douglas-fir, ponderosa pine, Engelmann spruce and lodgepole pine. In Colorado, a total of 109.8 million board feet of timber was cut in 1999. This is equivalent to 8 percent of total consumption of lumber, timbers, paneling, firewood and roundwood (log homes, agricultural fencing, utility poles, highway pilings, and mine props).[30] Manufacturing byproducts from firms located in or near the Front Range may be available for energy depending on the competing uses and costs of the byproducts. The remainder of the wood products consumed in Colorado is manufactured in other states and countries. Therefore, residues associated with their manufacture are not likely to be available. However, clean, untreated residues from the use of lumber and other wood products in construction and remodeling may be available. These materials are included in the category of construction and demolition waste.

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[30] Lynch, Dennis L. and Kurt Mackes. September 2001. Wood Use in Colorado at the Turn of the 21st Century. USFS Rocky Mountain Research Station. RMRS-RP-32. p. 23

Table 4-7. Quantities of major wood products consumed in Colorado and typical tree species used in their production

Product type	Species	Volume used	Volume units
Primary products			
Lumber for residential/structural framing and remodeling	Pine, fir, hemlock and spruce: Western U.S. (65% of total); Southern U.S. (10% of total); and Canada (25% of total)	830.7	million board feet
Log homes	Engelmann spruce, lodgepole pine, ponderosa pine and Douglas-fir	19.2	million board feet
Landscape timbers	predominantly southern yellow pine, but also fir, hemlock, red pine, lodgepole pine, southern yellow pine, and ponderosa pine	11	million board feet
Agricultural fencing	lodgepole pine	2.25	million board feet
Residential fencing	western red cedar, radiata pine, redwood	38.6	million board feet
Decking	redwood mostly, some southern yellow pine	72.2	million board feet
Utility poles	southern yellow pine, lodgepole pine, Douglas-fir	27.4	million board feet
Pallets	80% is softwood lumber from Pacific Northwest, Inland Empire and Canada. Hardwood lumber from Nebraska, Kansas or Missouri.	50	million board feet
Secondary products			
Wood components			
Doors	Many hardwood and softwood species	0.792	million units
Cabinets		0.596	million units
Molding		25.6	million linear feet
Flooring		0.6	million square feet
Windows		0.711	million units

Pallets and wooden container manufacturing and disposal are a significant industrial source of wood residues, a portion of which may be available for biomass energy. Nationwide there is a trend towards a reduction of the volume of pallets that is being disposed of in a landfill. The National Wooden Pallet and Container Association (NWPCA) tracks pallet manufacturing, recycling and disposal trends. The NWPCA reports that there are approximately 1.9 billion pallets in use throughout the United States. Each year 400 million new pallets are produced and about 175 million are repaired or recycled. Another 190 million are disposed of in landfills and 35 million are diverted from the waste stream and reprocessed into other products. Since 1993, the percentage of pallets put in landfills has been reduced from 59 percent to 28 percent.[31] Using pallet material that is not suitable for a higher value product for energy is one way to help continue this trend. Pallet manufacturers and recyclers generate pallet waste in the form of whole pallets, pallet components or shredded or chipped biomass.

[31] Lynch, Dennis L. and Kurt Mackes. September 2001. p. 8.

Construction and demolition residues include a wide variety of residues from residential and commercial construction, remodeling and demolition. Wood construction debris includes but is not limited to trim ends, edges and other scrap material from lumber, fencing, decking and other uses. Demolition residues include all forms of recoverable wood residues from building demolition. Often, construction and demolition residues include treated or painted wood products and can be commingled with other building materials. Treated, painted wood and foreign materials can include substances such as metals or solvents that can cause environmental problems when burned. As a result, care must be taken to ensure that only clean, untreated, unpainted wood materials from construction sites are used and that there is little contamination from other materials. A significant effort must be made to ensure that clean wood waste remains separate from other materials at the construction or building fabrication site. Separation of wood materials at a disposal site may also be possible, but is less likely to ensure that commingling of clean wood with other materials does not occur. It is difficult to ensure that wood from demolition sites is free of harmful contaminants, so it is not a recommended feedstock for a biomass fuel.

4.2.2 Data Sources and Analytical Approach

Two methods of estimating annual wood waste generation were used to provide a range of values. In the first method, a residue factor providing average annual residue generation by business type was multiplied by the number of establishments by business type to estimate annual wood residue. In the second, a per capita factor for residue generation was multiplied by the population of a region to estimate annual wood residue generation.

Several sources, shown in Table 4-8, were referenced to provide residue factors for the two methods. Each report used a slightly different classification of business type, or focused on a specific portion of the wood waste stream, which resulted in different estimates residue generation by businesses or on a per capita basis. The analysis for this report attempted to reconcile the differences by using the median value for each business type. Similarly, for the population-based estimates, this analysis used the median value for each multiplication factor from all reports analyzing that generation sector. Where a median value was not available, an average value was used.

Table 4-8. Sources used in analysis of wood waste generation from various sources

1. NEOS Corporation. Urban Wood Waste Resource Assessment, the State of Indiana. February 1995. Indiana Department of Commerce and GLRBP
2. Wiltsee, G. 1998. Urban Wood Waste Resource Assessment. NREL/SR-570-25918
3. NEOS Corporation. Wood Pellet Manufacturing in Colorado: An Opportunity Analysis. State of Colorado Office of Energy Conservation, and United States Department of Energy: Western Regional Biomass Energy Program. Contract No. 6S-90WA05637, February 1993
4. NEOS Corporation. Colorado Front Range Wood Resource Assessment. Front Range Forest Health Partnership. Denver, CO. April 1997.
5. NEOS Corporation. Urban Tree Residues: Results of the First National Inventory. September 1994. International Society of Arboriculture Research Trust, Allegheny Power Service Corporation, and National Arborist Foundation.

Table 4-9 shows the residue factors by business type used to estimate biomass generation from the number of establishments within each business type. Note that "total Urban Tree" includes "Landscaper", "Lawn & Garden" and "Commercial tree care", but that the numbers are not additive. These categories came from different reports. The median value of the factors for these three sub-categories was used to estimate the factor for total Urban Tree and for municipal solid waste (MSW) wood. Similarly, "Industrial wood" includes the "Pallet manufacturing", "Primary mill", and "Secondary mill" categories, and the multiplication factor is the median value of these three factors. The first column of Table 4-9 shows the data source for each row. The number refers to the sources listed in Table 4-8.

Table 4-9. Residue factors used to estimate biomass generation from the number of establishments within each business type

Firm type	Biomass generation (tons/establishment-year)				Source
	Min	Max	Median	Average	
Wood products manufacturers					
Primary processors	7	459	162	191	1
Secondary processors	188	188	188	188	1
Pallet Manufacturers	413	6,957	562	1,352	1
UTR					
Landscapers	47	256	783	561	5
Commercial Tree Care	139	15,152	1,506	2,776	4
Lawn & Garden	NA	NA	NA	508	5
Land Clearance/ Excavator	NA	NA	NA	171	5
Municipal Tree Care	NA	NA	NA	1,610	5

For urban wood residues, biomass generation is reported in tons as received. Residues from wood products manufacturers are lower in moisture content than UTR; in the overall biomass summary, the moisture content of all materials is adjusted to bone dry tons (BDT) to provide an equivalent basis for comparing quantities.

Table 4-10 provides the per capita residue factors used to estimate biomass generation. The residue categories do not match those in Table 4-9. However, assuming a large proportion of the UTR from landscaping, commercial and municipal tree care, lawns and gardens and land clearing, parks and recreation and utilities become municipal solid waste, a rough side-by-side comparison can be made between the results of the two methods.

Table 4-10. Per capita urban wood residue generation factors

Residue type	Annual biomass generation (tons/person-year)
Recoverable wood from MSW	0.209
Wood products manufacturers	0.048
Construction and demolition wood	0.076
Total urban wood	0.333

Wiltsee, G. 1998. Urban Wood Waste Resource Assessment. NREL/SR-570-25918

Table 4-11 provides the number of business establishments in each county by business type and county-level population used to estimate biomass generation vis-à-vis the two methods.

Table 4-11. Number of establishments by business type by county

County	Excavator/ Land Clearing	Land-scaping	Lawn & garden	Pallets	Primary mill	Secondary mill	Commercial tree care	Total
Boulder	44	77	35		8	37	14	225
Chaffee	22	3			10	4	2	42
Clear Creek	4							4
Custer	3							3
Denver	21	59	37	3	5	81	20	248
Douglas	51	64	22		3	12	7	160
El Paso	80	118	60	3	5	44	22	355
Fremont	27	5	3		2	3	2	47
Gilpin	1							1
Grand	29	7			18	1	1	60
Huerfano	4	1				1	1	8
Jefferson	77	93	41	1	12	20	36	306
Lake	6				2	1		10
Larimer	84	95	51	1	24	34	21	326
Las Animas	9	3	1		2	1	3	21
Park	23	1			9	1		34
Pueblo	35	39	15	3	2	12	13	129
Saguache	1					1		2
Teller	9	4			11	1	1	26
Total	530	569	265	11	113	254	143	2007

Source: InfoUSA.com. Colorado and Counties 2000.

4.2.3 Urban Wood Residue Generation

An estimated 887,137 BDT of biomass is generated from urban sources each year (Table 4-12). Urban tree residues, consisting of wood biomass from excavation and land clearing, lawn and garden, wood recycling and commercial tree care, make up 94 percent of the total. By contrast, industrial wood biomass, including pallets, primary manufacturing and secondary manufacturing residues, make up only 6 percent of the total.

Additional urban biomass generators include municipal and utility tree trimming operations. Estimates of generation from these sources are not included in Table 4-12 because little information is available on the extent to which utilities and municipalities conduct thinning in the area. An average or median of many utilities could be used to represent this quantity, but this could result in a high degree of error because utility service territories and municipalities differ widely in the extent to which they need to conduct vegetative management on their land.

Table 4-12. Annual biomass generation by business type (tons/year), estimated using median biomass generation for each establishment

County	Excavator / Land Clearing	Lands-caper	Lawn & Garden	Pallet Mfg	Primary mill	Secondary mill	Commercial tree care	Total
Boulder	7,535	60,291	8,665		1,294	6,568	21,085	105,439
Chaffee	3,768	2,349			1,618	751	3,012	11,497
Clear Creek	685							685
Custer	514							514
Denver	3,596	46,197	9,160	1,685	809	14,263	30,121	105,831
Douglas	8,734	50,112	5,447		485	2,252	10,542	77,572
El Paso	13,700	92,394	14,855	1,685	809	8,070	33,133	164,645
Fremont	4,624	3,915	743		324	563	3,012	13,180
Gilpin	171							171
Grand	4,966	5,481			2,912	188	1,506	15,053
Huerfano	685	783				188	1,506	3,162
Jefferson	13,186	72,819	10,151	562	1,941	3,378	54,218	156,255
Lake	1,028				324	188		1,539
Larimer	14,385	74,385	12,626	562	3,883	6,005	31,627	143,473
Las Animas	1,541	2,349	248		324	188	4,518	9,167
Park	3,939	783			1,456	188		6,365
Pueblo	5,994	30,537	3,714	1,685	324	2,252	19,579	64,084
Saguache	171					188		359
Teller	1,541	3,132			1,780	188	1,506	8,146
Grand Total	90,763	445,527	65,608	6,178	18,280	45,415	215,367	887,137
Percent of total	10%	50%	7%	1%	2%	5%	24%	100%

Using per capita biomass generation factors resulted in an estimate of 303,275 tons of wood waste per year, as shown in Table 4-13. This total includes a category for construction and demolition wood. Construction and demolition wood waste generation was not estimated using the prior method. It is difficult to directly compare the two estimates because the residue categories for the two estimation methods do not directly correspond. The estimates in Table 4-12 contain a broader array of residues, hence it is not surprising that the overall quantity is higher. However, excluding construction and demolition wood waste from generation estimates in Table 4-13 (because this residue category was not included in estimates that used the number of establishments as the basis for biomass generation estimates) results in estimated urban biomass generation of 117,397 BDT per year. This is a considerably smaller quantity than the estimates based on the number of establishments, and it compares fairly closely with the combined primary and secondary residue generation estimate of 63,695 from Table 4-12.

Table 4-13. Annual wood biomass generation using per capita residue generation figures (tons per year)

County	Population [1]	Industrial wood	Construction and demolition wood	Total
Boulder	273,719	13,139	20,803	33,941
Chaffee	15,544	746	1,181	1,927
Clear Creek	8,770	421	667	1,087
Custer	3,317	159	252	411
Denver	517,349	24,833	39,319	64,151
Douglas	158,773	7,621	12,067	19,688
El Paso	477,912	22,940	36,321	59,261
Fremont	43,946	2,109	3,340	5,449
Gilpin	4,485	215	341	556
Grand	11,731	563	892	1,455
Huerfano	7,512	361	571	931
Jefferson	494,065	23,715	37,549	61,264
Lake	7,199	346	547	893
Larimer	236,326	11,344	17,961	29,304
Las Animas	14,388	691	1,093	1,784
Park	13,654	655	1,038	1,693
Pueblo	132,161	6,344	10,044	16,388
Saguache	5,515	265	419	684
Teller	19,399	931	1,474	2,405
Total	2,445,765	117,397	185,878	303,275

[1] Source: InfoUSA.com. Colorado and Counties – 2000.

Because the counties in the study area are mostly rural, both estimation methods are likely to overestimate biomass generation. This bears some explanation. The method using median biomass generation by wood products establishments probably overestimates residue generation in rural areas, where secondary processors are most likely smaller than the average or median facility. Evidence that the per capita method results in an overestimate is less clear. These per capita generation factors were taken from a survey of generators, but using the median factor may similarly result in an overestimate if residue generation on a per capita basis is higher in more populous counties.

4.2.4 Urban Wood Residue Availability and Cost

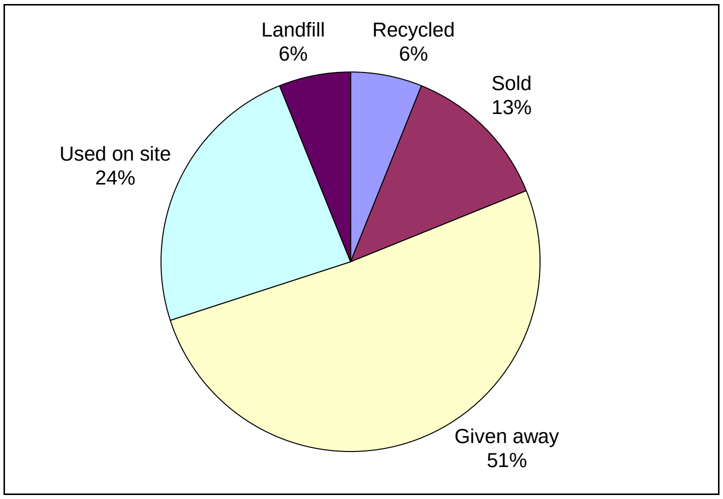
To further develop the urban wood resource, a large quantity of materials would have to be collected through an expanded and modified collection and processing infrastructure from the existing waste disposal system. A greater degree of source separation would be required to capture certain waste streams to prevent contamination with unsuitable materials. However, all of this can actually present a significant opportunity. In many areas, there is a gap for waste pickup and disposal services for wood and other biomass materials from residential and commercial businesses that would otherwise need to schedule special waste pickup or drop materials off at a disposal site in order to clean up their property.

Issues surrounding UTR availability, nonetheless, are numerous:

- Very few, if any, companies actually track their generation of wood residues - most companies only provided estimates of the material they produce;
- The industries considered for this study are diverse, ranging from "mom and pop" operations to large corporations with several hundred employees;
- There is frequent turnover of companies within both the UTR and primary/secondary manufacturers sectors;
- Although the survey data used to develop residue generation factors accounted for this potential, the potential for double-counting in resource assessment is significant because many utilities and municipal departments use private sector companies to perform tree trimming, tree removal and landscaping operation.

The results of a prior Front Range fuels assessment survey of urban wood end uses were used to estimate urban wood residue generation for this study. The prior assessment indicated that 50 percent of the primary or secondary residues generated were either landfilled or given away. For this study, this proportion of overall primary and secondary residue generation was considered available for use.

Estimating UTR availability is slightly more complicated. Figure 4-5 shows end uses of UTR based on the results of a survey of 69 UTR generators from the prior Front Range fuels assessment. For purposes of this study, available UTR was calculated from total generation assuming that materials that are landfilled or given away (57 percent of total) could be available for use at a biomass energy facility. This is a conservative estimate, as developing markets could make more of this material available. Using a conservative estimate of availability also helps capture a portion of the segment that could be considered "unrecoverable" because the resource is diffuse and not all generators will be willing or able to participate in recovery.



Source: NEOS Corporation. Colorado Front Range Wood Resource Assessment. Front Range Forest Health Partnership. Denver, CO. April 1997.

Figure 4-5. Estimated end uses of UTR in Front Range

Table 4-14 shows estimated urban wood resource availability in Front Range counties. An estimated 500,777 GT of biomass per year could be available for biomass energy, 93 percent of which is composed of UTR and 7 percent is from manufacturing (pallet manufacturing, primary processing and secondary wood products manufacturing).

Table 4-14. Estimated urban wood resource availability (tons per year)

County	Excavator/ Land Clearing	Land-scaper	Lawn & Garden	Pallet Mfg	Primar y mill	Secondar y mill	Commercia l tree care	Total
Boulder	4,295	34,366	4,939	-	647	3,284	12,018	59,550
Chaffee	2,147	1,339	-	-	809	375	1,717	6,388
Clear Creek	390	-	-	-	-	-	-	390
Custer	293	-	-	-	-	-	-	293
Denver	2,050	26,332	5,221	842	404	7,131	17,169	59,151
Douglas	4,978	28,564	3,105	-	243	1,126	6,009	44,025
El Paso	7,809	52,665	8,467	842	404	4,035	18,886	93,108
Fremont	2,636	2,232	423	-	162	282	1,717	7,451
Gilpin	98	-	-	-	-	-	-	98
Grand	2,831	3,124	-	-	1,456	94	858	8,363
Huerfano	390	446	-	-	-	94	858	1,789
Jefferson	7,516	41,507	5,786	281	971	1,689	30,904	88,654
Lake	586	-	-	-	162	94	-	841
Larimer	8,199	42,399	7,197	281	1,941	3,003	18,028	81,048
Las Animas	879	1,339	141	-	162	94	2,575	5,190
Park	2,245	446	-	-	728	94	-	3,513
Pueblo	3,416	17,406	2,117	842	162	1,126	11,160	36,229
Saguache	98	-	-	-	-	94	-	191
Teller	879	1,785	-	-	890	94	858	4,506
Total	51,735	253,950	37,396	3,089	9,140	22,708	122,759	500,777

Primary and secondary wood product manufacturer and UTR costs for material that ordinarily is landfilled or given away would often be limited to processing (chipping or grinding) and transportation costs. Costs to chip and grind wood residues range from $4.50 to $6 per GT, assuming 50 percent moisture content.[32] Transportation costs depend on the size of the truck used, but for using tractor trailers to transport materials from a centralized collection and processing facility, transport costs are similar to those for forest biomass trucking costs, which range from $6.20 to $14.20 for distances ranging from 10 to 100 miles.[33] Combining these costs suggests that urban wood residue costs would range from $10.70 to $20.20 per GT delivered.

One way to facilitate further development of this resource would be to co-locate and publicize wood recycling centers at landfills and waste transfer stations and expand existing facilities. This can help alleviate the time and resources wood waste generators spend in otherwise disposing of wood residues. Communities and waste management facilities might be able or willing to share the costs of developing and operating a central collection and processing facility in order to prolong the life of waste disposal facilities and to encourage fuels reduction in the urban-wildland interface.

For materials that are currently sold, a biomass energy facility would likely have to meet or exceed current market prices for wood residues. A recent study by the USFS quantified the retail sales quantities and values for a variety of wood residues in Colorado (Table 4-15). There are additional processing costs for some residues (chipping/screening, bagging and dyeing in some landscape mulch applications) but these values approximate the price that an energy producer would have to pay to obtain these materials. An energy producer would have to pay at least $15.00 to $26.00 per GT delivered for forest manufacturing residues to make it worthwhile for a wood products manufacturer to sell residues for energy. This does not include residues sold for animal bedding. Energy will not compete with bagged animal bedding sold on a retail level. The price may be somewhat lower if there is additional processing needed to make the residue salable that would not be required if it were sold as fuel.

Table 4-15. Prices and Total Volumes of Residue Products Sold in Colorado

End use	Type of residue	Volume used (cubic yards)	Price/unit volume ($/cubic yard)	Weight used (GT)[a]	Price/unit weight ($/GT)
Mulch	Chips	130,000	24.25	61,905	25.57
Dairy bedding	Sawdust/shavings	122,850	7.00	58,500	14.70
Horse bedding	Chips, sawdust and shavings	800,000	10.00	380,952	21.00
Poultry bedding	Chips, sawdust	75,000	12.00	37,500	25.20

[a] Note: Assuming 2.1 cubic yards per dry ton and 50% moisture content. [b] High quality bagged material sold in small quantities at retail outlets. Source: Lynch, Dennis and Kurt Mackes. September 2001. Wood Use at the Turn of the Century. USDA Forest Service Rocky Mountain Research Station. RP-RMRS-RP-32.

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[32] TSS Consultants. November 11, 2002. A Preliminary Feasibility Assessment for a Biomass Power Plant in Northeastern Arizona. Prepared for Greater Flagstaff Forests Partnership, Rancho Cordova, CA.
[33] WRBEP 1999.

Other factors related to the availability of residues include willingness of mill owners and operators to divert residues to alternative markets, and differences in transportation cost.

4.3 Biomass Properties

This section describes physical and chemical characteristics of various forms of biomass and also describes processing and conversion issues specific to different biomass types.

4.3.1 Fuel Heating Value, Chemical Composition and Physical Traits of Wood Biomass

Wood fuel characteristics greatly impact the combustion process and therefore the choice of conversion technologies. This section provides information from a prior biomass study conducted by the Nevada Tahoe Conservation District, updated to reflect the types of wood biomass that are predominant in Colorado.[34]

Cellulosic biomass is derived from plant material. The primary chemical constituents of biomass include cellulose, hemicellulose and lignin. Other constituents include proteins, gums and resins and ash-forming minerals. Biomass varies in these chemical constituents and also in physical form, moisture content, energy content, and bulk composition. All of these affect the conversion of biomass to energy, fuels and chemicals.

Design engineers use heat content values to size a biomass conversion system. The heat content of wood and bark varies considerably due to differences in the chemical composition of the sample. As a general rule, softwoods contain a higher percentage of volatiles in the form of gums and resins. Softwoods, therefore, often, but not always, have a higher heat content per pound than hardwoods.

Ultimate analysis, proximate analysis and heating value analysis are three standard tests used to provide information on the fuel value, combustion characteristics and emissions impacts of different forms of biomass. The proximate analysis test provides the fixed carbon, volatile and ash content of biomass. The ultimate analysis provides an elemental analysis of the carbon (C), hydrogen (H), oxygen (O), sulfur (S) and nitrogen (N) content of biomass. Also provided is the measured higher heating value (HHV) for the samples.

Table 4-17 provides ultimate and proximate analysis and fuel heat value test results for forest biomass, UTR and C & D wood. Table 4-18 provides ultimate and proximate analysis test results for tree species used in primary and secondary wood products manufacturing, and for manufacturing residues where test results are available. The values for “source” in Table 4-17 and Table 4-18 correspond to the numbered sources in Table 4-16.

[34] Nevada Tahoe Conservation District. September 1997. Evaluation of Biomass Utilization Options in the Lake Tahoe Basin. South Lake Tahoe, CA. Prepared by NEOS Corporation (Now Global Energy Partners, LLC).

Table 4-16. Sources for ultimate analysis, proximate analysis and heating analysis results

1) Reed, Tom B. Biomass Energy Foundation. Biogas - Ultimate and Proximate Analysis. On-line: http://www.woodgas.com/proximat.htm
2) U.S. DOE Office of Transportation Technology Biofuels Program. Biomass Feedstock Composition and Properties Database. On-line: http://www.ott.doe.gov/biofuels/properties_database.html
3) PHYLLIS. Energy Research Center of the Netherlands. On-line: http://www.ecn.nl/phyllis/
4) R.L. Bain and W.A. Amos (NREL) and M. Downing and R.L. Perlack (ORNL). March 2003. Biopower Technical Assessment: State of the Industry and Technology. NREL/TP-510-33123.

Thermal energy is released from organic materials as the carbohydrates and other hydrocarbons (lignin and volatile chemicals) are ultimately reduced to carbon dioxide and water. The amount of usable thermal energy that can be obtained from fuel is also known as the heat or energy content, latent heat or energy, the heat of combustion, and the higher heating value (HHV). On a dry, ash-free basis, most wood biomass has an energy content in the range of 8,000 to 9,000 Btu per pound (HHV). Removing the moisture from the feedstock may consume a large portion of its total energy content, reducing the available product yield in terms of heat or fuel.

Softwoods generally contain a higher percentage of volatile hydrocarbons than do hardwoods, in the form of gums and resins. As a result, softwoods often, but not always, have higher energy content than hardwoods. Oven-dry softwood and bark have energy contents ranging from 8,300 Btu per pound to 9,500 Btu per pound. The energy content of oven-dry hardwood and bark ranges from 7,300 Btu per pound to 9,600 Btu per pound. Ash-forming minerals generally contain no energy content. Therefore, as the ash content increases, the HHV decreases.

The volatile chemical content of a feedstock is an important consideration in the biomass combustion processes because of the potential for volatile organic compound emissions that could result from incomplete combustion.

Biomass ash contents can be used to determine the likely quantities of ash that will be left over and require disposal.

Sulfur content of biomass is one determinant of sulfur dioxide (SO_2) emissions, which is also affected by combustion technology and emissions control system selection and operation. In addition to polluting the atmosphere, sulfates form deposits on boiler convection tubes, contributing to slagging problems. Overall, biomass has lower sulfur content and particulate emissions than coal, so biomass utilization benefits the environment by reducing the emissions of SO_x and ash associated with coal-fired boilers.

Table 4-17. Heating value, ultimate and proximate analysis results for forest biomass, UTR and C&D wood

		Proximate analysis			Ultimate analysis						
		Volatiles	Fixed C	Ash	C	H	O	N	S	HHV	Cl
Biomass type	Source	wt%	wt%	wt %	wt%	wt %	wt%	wt%	wt%	Btu/lb	wt%
Forest biomass											
Softwoods											
Douglas-fir	4	N/A		0.8	52.3	6.3	40.5	0.1	0	9050	
Douglas-fir	1	81.5	17.70	0.8	52.3	6.3	40.5	0.1	0.00	9056	-
Fir, white	1	83.2	16.58	0.3	49.0	6.0	44.8	0.1	0.01	8582	-
Fir, white	4	N/A		1.5	49.0	6.0	44.8	0.1	0.01	8367	
Pine, lodgepole	1	84.8	15.0	0.2	N/A	N/A	N/A	N/A	N/A	N/A	-
Pine needles	4	N/A		1.5	48.2	6.6	43.7	N/A	N/A	8669	
Pine, ponderosa	1	82.5	17.17	0.3	49.3	6.0	44.4	0.1	0.03	8613	-
Pine, ponderosa	4	N/A		0.3	49.3	6.0	44.4	0.1	0.03	8470	
Spruce	4	N/A		3.8	51.8	5.7	38.3	N/A	N/A	8759	
Hardwoods											
Aspen	1	65.8	30.1	4.1	N/A	N/A	N/A	N/A	N/A	N/A	-
UTR/C&D wood											
Christmas trees	4	N/A		5.2	51.6	5.6	36.7	0.5	0.4	9009	--
Demolition wood	4	N/A		13.1	46.3	5.4	34.5	0.6	0.1	7916	0.05
Mixed waste paper	4	N/A		8.3	48.0	6.6	36.8	0.1	0.07	8934	
Municipal solid waste	4	N/A		12.0	47.6	8.0	32.9	1.2	0.3	8546	
Urban wood waste	4	N/A		2.5	48.8	5.8	39.6	0.3	0.07	8361	0.05
Wood - land clearing	4	N/A		16.5	42.3	5.0	35.8	0.3	0.06	7408	0.02
Wood - yard waste	4	N/A		20.4	41.5	4.8	32.2	0.8	0.2	7009	0.3

Table 4-18. Ultimate and proximate analysis for biomass types used by primary and secondary processors

Biomass type	Source	Proximate analysis			Ultimate analysis				
		Volatiles	Fixed Carbon	Ash	C	H	O	N	S
		wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%
Alder, red	1	87.10	12.50	0.40	49.55	6.06	43.78	0.13	0.07
Alder, red	4	N/A		0.4	49.55	6.06	43.78	0.13	0.07
Alder/fir sawdust	4	N/A		4.13	51.02	5.8	68.54	0.46	0.05
Cedar, western red	1	80.2	18.0	1.8	N/A	N/A	N/A	N/A	N/A
Cherry	4	N/A		1.35	48.52	5.81	42.97	0.31	0.02
Douglas-fir bark	4	N/A		1.2	56.2	5.9	36.7	0	0
Douglas-fir	4	N/A		0.8	52.3	6.3	40.5	0.1	0
Douglas-fir	1	81.50	17.70	0.80	52.30	6.30	40.50	0.10	0.00
Fir, white	1	83.17	16.58	0.25	49.00	5.98	44.75	0.05	0.01
Fir, white	4	N/A		1.52	49	5.98	44.75	0.05	0.01
Fir, mill waste	4	N/A		0.41	51.23	5.98	42.29	0.06	0.03
Forest residuals	4	N/A		3.97	50.31	4.59	39.99	1.03	0.11
Furniture waste	4	N/A		3.61	49.87	5.91	40.29	0.29	0.03
Hemlock, western	4	N/A		2.2	50.4	5.8	41.4	0.1	0.1
Hemlock, western	1	84.80	15.20	2.20	50.40	5.80	41.10	0.10	0.10
Hickory	4	N/A		0.7	49.7	6.5	43.1	0	0
Hog fuel	4	N/A		16.89	45.36	5.63	42.13	0.18	0.02
Maple	4	N/A		0.5	49.54	6.11	49.54	0.1	0.02
Mixed wood	4	N/A		1.44	49.31	6.03	42.98	0.18	0.02
Mixed wood (90% red oak)	4	N/A		0.94	48.51	6.17	44.22	0.12	0.04
Oak	4	N/A		2.09	49.83	5.87	41.82	0.32	0.04
Oak, red	4	N/A		2.76	49.34	5.93	41.74	0.07	0.13
Oak, red sawdust	4	N/A		0.31	49.96	5.92	43.77	0.03	0.01
Oak, tan	4	N/A		0.2	48.67	6.03	44.99	0.06	0.04
Oak, tan	4	N/A		0.5	48.34	6.12	44.99	0.03	0.03

Table 4-18. Continued

Biomass type	Source	Proximate analysis			Ultimate analysis				
		Volatiles	Fixed Carbon	Ash	C	H	O	N	S
		wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%
Oak, white	4	N/A		1.52	49.48	5.38	43.13	0.35	0.01
Pine, lodgepole	1	84.8	15.0	0.2	N/A	N/A	N/A	N/A	N/A
Pine, ponderosa	1	82.54	17.17	0.29	49.25	5.99	44.36	0.06	0.03
Pine, ponderosa	4	N/A		0.29	49.25	5.99	44.36	0.06	0.03
Pine	4	N/A		0.13	51.27	6.19	42.13	0.13	0.13
Pine bark	4	N/A		2.9	52.3	5.8	38.8	0.2	0
Pine, loblolly, bark	4	N/A		0.4	56.3	5.6	37.7	N/A	N/A
Pine, long leaf, bark	4	N/A		0.7	56.4	5.5	37.4	N/A	N/A
Pine, Monterrey	2	80.45	19.35	0.30	50.26	5.98	42.14	0.03	0.01
Pine, slash, bark	4	N/A		0.7	56.2	5.4	37.3		
Pine, southern yellow, untreated	4	N/A	N/A	1.3	52.6	7.02	40.1	N/A	N/A
Pine, sugar	1	98.1	3.1	0.5	N/A	N/A	N/A	N/A	N/A
Pine, western white	1	N/A	N/A	0.10	52.60	6.10	41.20	0.00	0.00
Pine, white	4	N/A		0.1	52.6	6.1	41.2	N/A	N/A
Pine, yellow	4	N/A		1.31	52.6	7	52.6	N/A	N/A
Poplar	4	N/A		1.33	48.45	5.85	43.69	0.47	0.01
Redwood	4	N/A		0.2	53.5	5.9	40.3	0.1	0
Redwood wastewood	4	N/A		0.6	53.4	6	39.9	0.1	0.1
Sawdust	4	N/A		0.36	51.33	6.13	41.97	0.12	0.02
Spruce	4	N/A		3.8	51.8	5.7	38.3	N/A	N/A

Moisture content greatly affects the quality of biomass fuel. Moisture content can be measured on a wet or a dry basis. In engineering calculations moisture content is expressed as a percent of the total weight. This is the wet basis method. In the dry basis method, the moisture content is expressed as a percent of the dry weight of the wood. This report uses the wet basis method.

The moisture content of freshly harvested forest residues typically varies from 40 to 60 percent by weight, and can be higher, especially if exposed to recent precipitation.[35] Wood typically ranges from 18 to 25 weight percent MC or more after air-drying for approximately one year. The actual moisture content depends on climate, storage conditions and bulk characteristics. Bark often has lower moisture content than does wood.

In combustion processes, high moisture content can lead to incomplete combustion, low thermal efficiency, low flame temperatures, excessive emissions, and the formation of tars and slagging problems. Maximum thermal efficiency is achieved when using a fuel with no moisture content, (referred to as oven-dry or bone-dry (bd)); but complete drying is often too costly or impractical. Woody and herbaceous biomass with moisture content in the range of 10 to 20 weight percent is considered optimal for conventional combustion systems.[36] Low moisture content is especially important for most pyrolytic gasification processes, where variations in the moisture content of the feedstock cause large variations in the quality of the gas product.[37] The costs of drying forest residues must be carefully weighed against the advantages of handling drier feedstock, and against incremental improvements in the thermal efficiency of the conversion process. Twenty percent, or more, of the total energy content of green wood may be consumed by thermal drying, reducing the available energy yield of the feedstock as heat or fuel.[38] Some fluid-bed combustors, however, are designed to operate with variable moisture contents of the feedstock up to 50 weight percent. Many large-scale combustion plants operate well with little apparent concern for the effects of moisture content in the biomass feedstock on the combustion process.[39] Pre-treatment involving size reduction and air-drying, and/or blending with dry fuel, may be adequate and cost-effective for such operations.

Fuels with high moisture contents have increased transportation costs since a large proportion of the weight being shipped is water. Because of the negative impact of moisture content on combustion processes and increases in delivered feedstock costs, a good rule is to attempt to minimize biomass moisture content of the delivered feedstock. This can be done by using a blend of fuels; lower moisture content mill residues such as sawdust can be used to offset higher moisture content forest biomass. Alternatively, it is possible to reduce moisture content through passive or active drying.

The most common problems associated with wood combustion are boiler slagging and fouling, erosion and corrosion, combustion instability, and particulate carryover.

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[35] Klass, Donald L. 1998. Biomass for Renewable Energy, Fuels, and Chemicals. San Diego: Academic Press. 161.
[36] Klass. 197.
[37] Klass. 165-67.
[38] Klass. 86, 87.
[39] Klass. 163.

High alkalinity also causes fouling and slagging in stoker type boilers and agglomeration (clumping) in fluidized bed combustion systems. Research indicates that fuels with ash alkali contents below 0.4 lb alkali per million Btu are not likely to cause slagging.[40] Herbaceous materials, annual crops, and woody prunings all have abundant alkali in the ash. [41]In general, whole-tree chips are higher in alkali content than are clean chips, due to the concentration of potassium salts and other organic compounds in the small branches, twigs and needles of the tree. Sodium and potassium compounds typically have low melting points resulting in increased slagging problems. Biomass rich in both potassium and chlorine can cause large amounts of slagging and fouling during combustion. Biomass ash samples are typically low in sodium content. Ash samples high in iron typically indicate presence of materials such as dirt or soil.[42] Quantities of oxides of sulfur (SO_x) are particularly useful for determining the emissions of SO_x during coal/wood co-firing applications.

Physical characteristics of fuel, such as density and particle size, affect combustion and material handling considerations. Changes in fuel density could cause combustion to occur in the wrong place in the boiler, upsetting the heat transfer scheme and therefore the boiler efficiency. Chipping, grinding and screening can control physical fuel characteristics. Because low-density materials occupy more space in truck trailers, they cost more per unit of weight to deliver and thus increase feedstock costs.

4.4 Summary of Biomass Availability and Cost

To develop a meaningful biomass resource total and facilitate comparison between residue categories, it was necessary to convert quantities reported with as-received moisture contents to BDT. Table 4-19 provides the moisture content values used to perform this calculation.

Table 4-19. Wood biomass moisture content assumptions

Residue type	Moisture content (%)	Source
Forest biomass[1]	50	U.S. Forest Service Forest Products Laboratory. Wood Handbook, Chapter 3. pp. 3 – 6.
Commercial tree care[1]	50	
Excavator/land clearance[1]	50	
Landscaper[1]	50	
Lawn & garden[1]	50	
Pallets[2]	10	Bain, R.L. and W.A. Amos (NREL) and M. Downing and R.L. Perlack (ORNL). March 2003. Biopower Technical Assessment: State of the Industry and Technology. NREL/TP-510-33123.
Primary residues[3]	45	
Secondary residues[4]	24	

[1]Average of heartwood/sapwood for ponderosa pine, Douglas-fir, aspen, hemlock, and white fir. [2] Kiln-dried material. [3] Average of coarse residue moisture content (ranges from 45 - 60 percent). [4] Average of sander dust and sawdust moisture content

[40] Miles, T.R., T.R Miles Jr., Larry L Baxter, Bryan M. Jenkins, Laurence L. Oden. Alkali Slagging Problems With Biomass Fuels, In Proceedings of the First Biomass Conference of the Americas, Held August 30 - September 2, 1993. NREL/CP-200-5768 DE93010050. pp. 406.

[41] R.L. Bain and W.A. Amos (NREL) and M. Downing and R.L. Perlack (ORNL). March 2003. Biopower Technical Assessment: State of the Industry and Technology. NREL/TP-510-33123.

42 R.L. Bain and W.A. Amos (NREL) and M. Downing and R.L. Perlack (ORNL). March 2003.

Table 4-20 provides an overall summary of biomass availability from urban and forest resources in the Front Range of Colorado.

Table 4-20. Summary of biomass availability from urban and forest sources in the Colorado Front Range (BDT/year)

County	Land Clearing	Land-scaping	Lawn & Garden	Wood products	Comm-ercial tree care	Forest biomass	Total	Power generation capacity (MW)[a]
Boulder	2,147	17,183	2,470	2,852	6,009	25,023	55,684	4.4
Chaffee	1,074	669	-	730	858	1,100	4,431	0.3
Clear Creek	195	-	-	-	-	-	195	0.0
Custer	146	-	-	-	-	10,324	10,470	0.8
Denver	1,025	13,166	2,611	6,400	8,585	-	31,787	2.5
Douglas	2,489	14,282	1,552	989	3,005	16,758	39,075	3.1
El Paso	3,905	26,332	4,234	4,047	9,443	31,901	79,861	6.2
Fremont	1,318	1,116	212	303	858	23,903	27,710	2.2
Gilpin	49	-	-	-	-	19,608	19,657	1.5
Grand	1,415	1,562	-	872	429	90,274	94,552	7.4
Huerfano	195	223	-	71	429	35,830	36,749	2.9
Jefferson	3,758	20,753	2,893	2,070	15,452	21,926	66,853	5.2
Lake	293	-	-	160	-	9,663	10,116	0.8
Larimer	4,100	21,200	3,599	3,602	9,014	24,131	65,645	5.1
Las Animas	439	669	71	160	1,288	3,095	5,722	0.4
Park	1,123	223	-	472	-	15,523	17,341	1.4
Pueblo	1,708	8,703	1,058	1,703	5,580	9,729	28,481	2.2
Saguache	49	-	-	71	-	828	948	0.1
Teller	439	893	-	561	429	9,764	12,086	0.9
Total	25,867	126,975	18,698	25,065	61,380	349,379	607,364	47.6
Percent of total	4%	21%	3%	4%	10%	58%	100%	100%

Forest biomass makes up 58 percent of the total biomass resource in the area, while urban sources (land clearing, landscaping, lawn & garden, commercial tree care, pallets, and wood products manufacturing) make up the remaining 42 percent.

Figure 4-6 shows the geographic distribution of the biomass resource. Grand County is the largest biomass generator. Larimer, Boulder, Jefferson and El Paso counties fall within the next tier of biomass generation. In Grand County, most of the biomass is from forest resources. In the second tier counties, biomass generation is more evenly distributed between urban and forest resources.

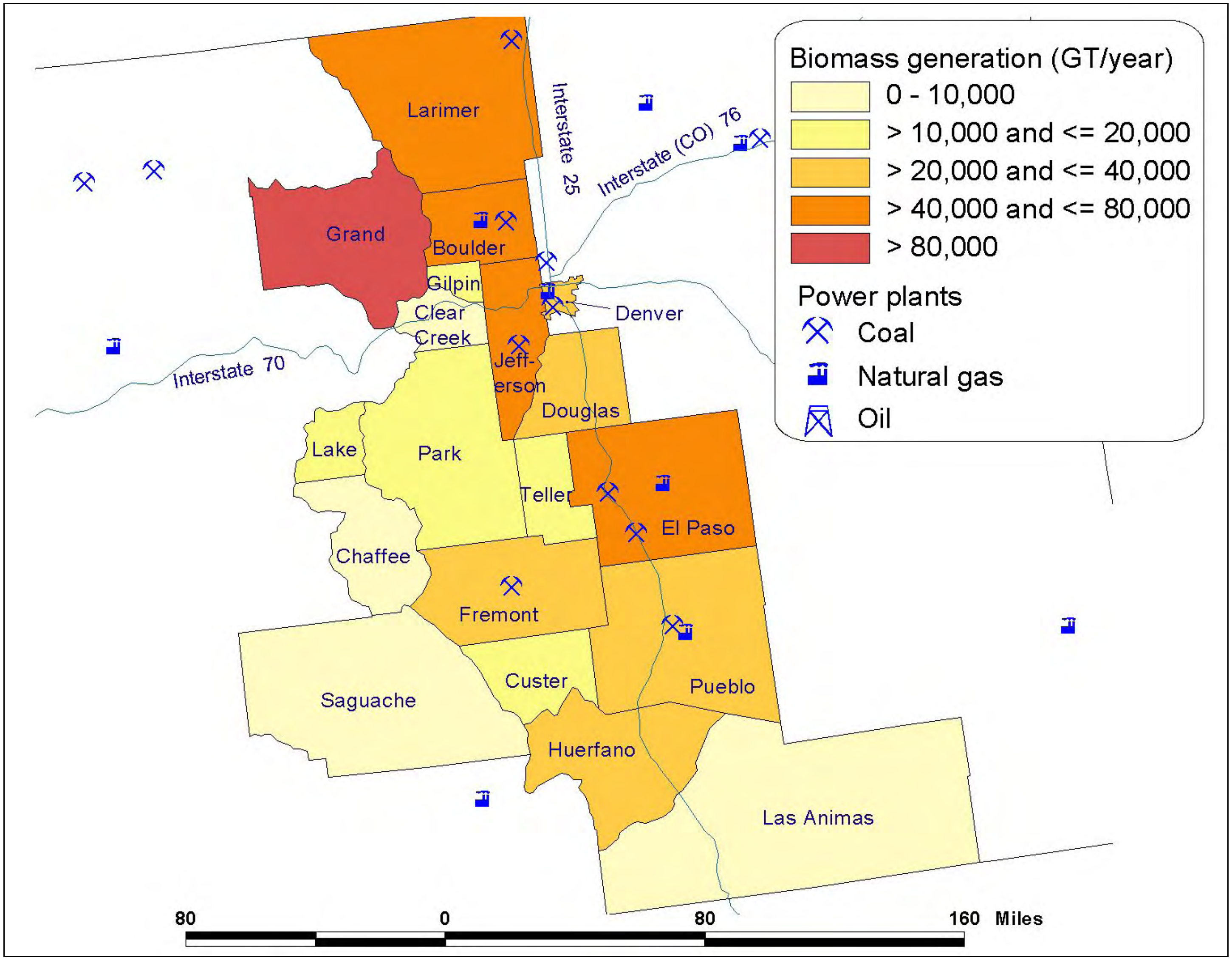

Figure 4-6. Estimated annual biomass resource generation in Colorado Front Range (GT/year)

5. BIOMASS ENERGY TECHNICAL POTENTIAL

This section provides information on biomass energy technologies, discusses specific applications of relevance to the Front Range, and provides an estimate of the potential capacity that could be available from biomass energy. Information on biomass technology vendors can be found in Appendix Gof this report.

5.1 Biomass Power Generation Technology

The two primary biomass energy conversion technologies are direct combustion and gasification. There are two major components to any biomass power generation system: an energy conversion device that produces useful energy in the form of heat or combustible gases and a prime-mover that can convert this energy to electricity. Biomass installations exhibit a considerable range of sizes from very small units (e.g., 5-10kW) to large facilities up to 50MW.

Prime movers include steam turbines, reciprocating engines, and gas turbines. Steam turbines are currently the only commercial means of producing power from biomass. Research is underway to improve technology to allow the use of gasification coupled with reciprocating engines or gas turbines to generate power. Contaminants in gas from biomass gasification currently reduce reliability and increase maintenance costs of engines and gas turbines, reducing their overall efficiency when compared with steam turbines.

While the common theme among the various technologies is the feedstock, the differing sizes and market sectors/applications creates challenges for summarizing representative performance characteristics. Furthermore, because many of the technologies, especially, the smaller unit sizes, are in developmental or demonstration phases, access to meaningful performance data is limited.

5.1.1 Combustion

Nearly all current U.S. biopower generation is based on direct combustion in plants operating at relatively low efficiency (14~24 percent energy to electricity). Combined heat and power (CHP) installations can increase the overall efficiency to 80 percent and is a common application in the forest products industry. Most biomass direct-combustion generation facilities utilize the basic Rankine cycle for electric power generation. Two technologies, stokers and circulating fluidized bed combustors (CFB), represent the vast majority of units deployed in the world today, and they are the workhorses of the biomass power industry.

5.1.1.1 Spreader-Stokers

Spreader stokers are a "grate" burning arrangement where the wood fuel is "flung" either pneumatically or mechanically onto the grate. Some heating and drying takes place in suspension but almost all combustion reactions occur on the grate. The grate design can be inclined, fixed or moving and be constructed of alloy steels, refractory materials, or high-temperature alloy steels (moving grates).

5.1.1.2 Fluidized Bed

Fluidized bed combustion (FBC) uses numerous air nozzles located at the furnace floor to suspend the fuel bed that consists of wood, sand, and/or limestone. Mixing in this type of atmosphere is highly efficient, yielding much improved heat transfer over other technologies. High volumes of air help to maintain low overall combustion temperatures. It is important to keep temperatures below the ash fusion temperature due to the large mass of inert bed material. While low temperatures result in low NOx (oxides of Nitrogen) formation, combustion efficiencies can be limited.

Key benefits of the technology are fuel flexibility and reduced emissions. The increased popularity of the FBC technology recently in the United States is due primarily to the reductions in SOx and NOx emissions. Higher sulfur coals can be burned without the need for expensive "backend" sulfur cleanup equipment. Also, the rate of reaction between nitrogen and oxygen to form nitrogen oxides rapidly decreases as the combustion temperature decreases. With an operating bed temperature of between 1,500^{0}F and 1,600^{0}F, the amount of theses oxides is much less than that of conventional combustion technologies. Lower combustion temperatures also allow for the combustion of high fouling and slagging fuels because combustion takes place at temperatures below their ash fusion temperature. Fuel flexibility is also realized when burning fuel with higher moisture content as is found in many biomass fuel feedstocks. Fluidized beds can burn wetter fuels due to the rapid heating of the fuel particles by the large mass of hot bed material and the long residence time that the fuel spends in the bed.

FBC combustion is technically accepted in the industry and has had numerous applications although mostly in large-scale applications. The capital and operating costs associated with the technology typically make it economically unfeasible in size ranges less than ten megawatts.

5.1.2 Gasification

The gasification process is used to convert a heterogeneous biomass feedstock to a consistent intermediate product (commonly called "producer gas") that can be used for heating, industrial process applications, electricity generation, and liquid fuels production. The main combustible components of producer gas are carbon monoxide, methane, and hydrogen. In addition to these gases, gasification produces nitrogen, carbon dioxide, oxygen, water vapor, char (carbon), tars and ash. The gasification process is similar to combustion, although there are some important variations.

The conversion of biomass to a low- or medium-heating-value producer gas *via* thermal gasification generally involves two processes, namely, pyrolysis and gasification. Pyrolysis releases the volatile components of the fuel at temperatures below 600^{o}C (1112^{o}F) via a set of complex reactions.

Biomass gasification systems offer several advantages over direct combustion systems. Gasification reduces corrosion compared to direct combustion because of the lower temperatures in the gases. Gasifiers can convert the energy content of a feedstock to hot combustible gases at eighty-five to ninety percent thermal efficiency. Also, the fuel throughput per unit area is greater for gasification than combustion, which means that smaller gasification units can process the same amount of fuel as larger combustion units. In addition, approximately eighty percent of the usable energy is in the form of chemical energy in the gas. If desired, the materials that cause slagging can be removed at relatively high temperatures through a gas clean-up process. These last two statements imply that the gas can be cleaned-up and used at higher temperatures without significant loss of sensible heat,[43] although the costs to do so can be considerable.

In advanced and high efficiency gasification power systems, biomass feedstocks are converted to gas, which is then fed through industrial or gas turbines (aero-derivatives and microturbines). Small biomass-fueled gasifiers are also available from a number of manufacturers (for example, Community Power Corporation of Littleton, Colorado www.gocpc.com). These units are mainly used for closed-coupled applications such as firing the gas in kilns, boilers, or small motive power engines. Small-scale biomass gasification facilities have been working in many developing countries such as Philippines, Africa, Brazil, India and other places. One of Community Power's 15 kW gasifiers has been installed at the high school in Walden, Colorado.

Due to the potential of high thermal efficiency, integrated gasification combined cycle (IGCC) technology is under development in the US and Europe for biomass in large-scale facilities. Work is being done in this technology incorporating fluidized bed gasification, combustion turbine and steam turbine combined cycles, and ceramic filter hot gas clean up to protect the combustion turbine from alkali deposits and corrosion.

5.1.3 Cofiring

The nearest term, low-cost option for the use of biomass is co-firing with coal in existing boilers. Co-firing refers to the practice of introducing biomass as a supplemental fuel source in high-efficiency boilers. Co-firing has been practiced, tested, or evaluated for a variety of boiler technologies, including pulverized coal boilers of both wall-fired and tangentially-fired designs, coal-fired cyclone boilers, fluidized-bed boilers, and spreader stokers. Extensive demonstrations and trials have shown that effective substitutions of biomass energy can be made in the range of up to 10-15 percent of the total energy input with little more than burner and feed intake system modifications to existing stations. Co-firing is one of the best near-term opportunities for biomass energy use in Colorado, provided willing industrial partners and/or utilities can be located.

5.1.4 Green Power and Green Tags – The Potential for Biomass Power

Renewable energy can be sold to retail customers through two primary mechanisms. These are:

- Utility green pricing programs; and
- Green Tags, also called renewable energy certificates or tradable renewable certificates.

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[43] Rutherford, R.D., Calvin B. Parnell and Wayne A. Lepori. Cyclone design for fluidized bed biomass gasifiers. ASAE Paper no. 84-3598. 1984.

Utility green pricing programs are offered by some utilities and enable consumers to purchase electricity from renewable resources directly through their local utility. Green pricing is an option that allows utility customers to voluntarily support a greater level of investment in renewable energy technologies. Through green pricing, participating customers pay a premium on their electric bill to cover the extra cost of the renewable energy. More than 80 utilities have either implemented or announced plans to offer a green pricing option.

A consumer buying green power through a utility green pricing program is buying both the electricity and the environmental attributes. The electricity provides the functionality to power lights and appliances, and the "green-ness" allows the consumer to support the generation of electricity from renewable, sustainable sources. Green pricing programs ask a subset of utility customers to fund a public good through voluntary contributions, rather than through public policy measures.

With green pricing transactions, the green power is delivered into the transmission system, where it is intermingled with all other power being transmitted and distributed. Utilities transport the power and deliver it to the customers. The environmental attributes associated with the green power source are, in effect, hitching a ride with the electricity as it is transmitted and distributed to the customer. The utility charges its green pricing customers more, e.g., 10 ¢/kWh instead of 8 ¢/kWh, to support the actual costs of purchasing power generated using renewable resources. In practice, the electricity flowing into the green power customer's home is no different from that flowing into any other home. The premium that the green power customer is paying doesn't make the power green, but makes part of the mix of power that goes into the entire system green.[44]

"**Green Tags**" are created when a grid connected renewable energy facility generates power. Green Tags are certificates that represent the environmental attributes or benefits associated with electricity generation from new renewable technologies. When a renewable energy site produces electricity that enters the grid, or offsets grid power, the electricity can be unbundled from the "green" attributes of that electricity. Those green attributes are quantified as Green Tags. Thus there are two distinct quantities formed--the electricity which enters the grid, and the Green Tags from that electricity.

Green Tags are used to assign a value to the environmental benefits of renewable energy. This value arises from offsetting electricity generated from fossil fuels, such as coal or natural gas. The renewable electricity takes the place of non-green power that would otherwise have been generated and delivered to the power grid. The green tag also represents the fact that the renewable energy was generated with better emissions, or pollution characteristics, than normal electricity.

The idea behind Green Tags is that the renewable attributes are associated with, but can be sold separately from, the electricity generated from renewable resources. The electricity is consumed on-site or sold in the conventional power market (via net metering or through a utility power purchase agreement) without accounting for its environmental attributes. The generating facility

[44] Bonneville Environmental Foundation, "Summary Description of BEF's Green Tag Product" October 2000.

can no longer make environmental claims for this power because the green tag now represents the entire package of environmental benefits associated with these specific megawatt hours. For example, a biomass power facility at a lumber mill that has sold its Green Tags may not claim to be "renewable powered." However, it could use language describing itself as "hosting a renewable energy facility."[45]

The Green Tags are sold separately to electricity service providers (wholesale) or consumers (retail) who wish to "green" their energy supplies. Purchasing Green Tags does not affect the consumer's traditional electric bill. Consumers continue to receive their electricity bill from their existing provider. That bill includes the cost of conventional electricity only. The consumer who buys Green Tags is billed separately for the renewable attributes. With Green Tags, the consumer is buying both electricity and 'green-ness' – but is buying them separately. The tag is purchased from a renewable generator or a third party marketer. Green Tags can be sold anywhere and are not restricted by geography or tied to the utility that is serving a particular territory. In other words, a generator in Colorado could sell Green Tags to a buyer located in Illinois, or any other state.

The difference between traditional green pricing transactions and Green Tag transactions has to do with the accounting and tracking mechanisms of the green attributes themselves. With Green Tag transactions, the electricity is generated and delivered to the transmission system, and the utility still takes power from the system and distributes it to the customers. The Green Tags are sold as a separate commodity directly to a customer. With green pricing, the customer buys "green power" from the local utility in a bundled format. In both cases, the customer ends up with the same reliability and power quality – and the same environmental benefits – but acquires them in different ways. Table 5-1 shows the differences between green power and Green Tags.

Table 5-1. Green power vs. green tags from consumer perspective

Green Pricing	Green Tags
Purchase from utility or power marketer	Purchased from a certified marketer, anyone who owns Green Tags. Anyone may purchase, regardless of geographic location.
Only available in some regions	Available anywhere
One transaction	Multiple transactions (energy on one bill; tags on another)
Premium determined by market. Expected range of 1/2 - 4¢/kWh	
Green premium MAY go to new renewables	Green tag premium DOES go to new renewables
Energy and green attributes paid on same bill	Energy bill unchanged. Green premium billed by wholesaler.

5.1.4.1 __Tradable Renewable Certificates__

The Center for Resource Solutions (CRS) has developed national standards for certifying and selling Green Tags. CRS calls these certified Green Tags "Tradable Renewable Certificates," or TRCs. CRS' guidelines can be found on line at http://www.green-e.org/pdf/trc_standard.pdf. TRCs are created when electricity is generated using renewable energy. Each TRC purchased covers a unique mega-watt hour (MWh) of electricity, generated from renewable sources. The

[45] On-line: www.mainstayenergy.com

certificate represents all of the environmental attributes or benefits of a specific quantity of renewable generation. The premium value of TRCs compensates for the extra costs associated with generating green electricity, leveling the playing field for green energy to compete with conventional types of energy production and creating revenue for green providers.

CRS also runs the Green-e program, which certifies that renewable electricity meets certain standards. Green-e has served since 1997 as a nationally recognized tool to help consumers identify environmentally superior renewable energy offerings. To earn Green-e certification, TRCs must originate from 100 percent new renewable facilities that generate energy from renewable sources. Once certified as new, the facility can sell TRCs throughout its lifetime. Certified TRC providers must agree to abide by the Green-e Code of Conduct and to submit its marketing materials to CRS to meet Green-e disclosure and truth-in advertising requirements.[46] There are other requirements that are intended to avoid double counting of the benefits.

According to the CRS standards, any on-grid customer sited facility is eligible to sell its Green Tags as long as it is using an eligible resource and the system is metered if it is over 10 kW in capacity. The main goal of the standards is to make sure that if the TRCs are sold, they are registered as having been sold, and therefore can only be sold to one party at a time. The minimum quantity of TRCs that can be sold is 150 kWh.

The market for TRCs is in the early stages of development, and range from ½ cent/kWh to 2.5 cents/kWh. The primary buyers of Green Tags right now include government agencies, environmental groups, businesses that wish to improve their public image, and utilities that need to meet state-mandated Renewable Portfolio Standards. Marketers and brokers also purchase Green Tags and then resell them to various retail level utility customers. As discussed earlier in this report, the Western Area Power Administration is currently aggregating federal customers who may be interested in purchasing Green Tags. The contact at WAPA who is overseeing this effort is Mike Cowan. He can be reached at 720-962-7245.

A number of major issues associated with TRCs must still be resolved in the U.S. before TRCs will enjoy widespread acceptance. These issues include: standardization of definitions, information, rules, and processes; resolving property rights and other legal questions; and, development or market structures to encourage capital investment.

5.1.4.2 TRCs and Forest Biomass

Presently, CRS does NOT consider the electricity resulting from forest biomass as an eligible resource to produce TRCs. In early 2003, McNeil staff participated in a conference call with the U.S. Forest Service and CRS. The purpose of the call was to discuss why electricity produced from biomass from forest thinning/wildfire mitigation programs is not eligible to be certified as green power. The main reason stated by CRS staff is that most of the environmental groups on their advisory board are opposed to including forest thinnings.

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[46] "Green-e Certifies First 'Green Tag' Product and Plans National Press Conference," www.eere.energy.gov/greenpower/0402_regen_pr.html, accessed May 27, 2003. More information available at www.resource-solutions.org or www.green-e.org.

One of the reasons for this opposition is that the groups wish to prevent the inclusion of forest biomass from non-sustainable forest management practices (primarily clear cutting) in fuel supplies for biomass energy facilities. However, many proponents of forest management recognize that there is a real difference between some timber harvesting operations and forest stewardship activities that are conducted for a variety of objectives including hazardous fuels mitigation and forest stand density reduction. Sustainable forestry guidelines and chain-of-custody tracking applied to wood products can also be applied to biomass energy feedstocks, and can help encourage biomass utilization. This would be a significant boon to the recognition of biomass by a broader constituency as a viable renewable energy resource for fuels and electricity.

This lack of recognition of forest biomass as an eligible renewable energy resource under CRS' guidelines for Green Tags transactions is a major barrier.

The forest health/biomass co-firing project that will be implemented by Aquila (as described in Section 3 of this report) will attempt to overcome the issue of certification for biomass electricity produced from forest thinnings.

5.1.5 The Role of Green Tags

Green Tags have begun to be used in the U.S. in response to the evolution of both electricity and air pollution emission markets. The initial role for Green Tags is that of a tracking and verification mechanism in conjunction with Renewable Portfolio Standard (RPS) programs such as that being implemented in the states of Nevada, California, Texas, Arizona and New Mexico. For the past two years, proposed RPS legislation in Colorado has been defeated in the state legislature. In 2003, the RPS bill did include electricity produced from biomass from forest thinnings, clean urban wood waste and mill residues as an eligible resource defined under the RPS.

The second role for Green Tags, being a tradable commodity, is just beginning to be recognized in the U.S. Pacific Gas and Electric's (PG&E) National Energy Group is selling Green Tags from its New York wind farm throughout the northeast region. The Los Angeles Department of Water and Power is selling Green Tags to whoever is interested. Some companies are beginning to offer renewable energy certificates to retail consumers in states that do not otherwise have renewable energy facilities.

Green Tags are also being used by a few organizations (e.g., the Bonneville Environmental Foundation (BEF), the Climate Neutral Network (CNN), and Businesses for Social Responsibility) that work with business and industry to reduce their environmental footprint. In these examples, greenhouse gas offsets are being purchased (through Green Tags) to reduce a company's net global carbon impact. At this time, the use of Green Tags incorporates a patchwork of rules, processes, and terminology. With the exception of a few state RPS rule-making proceedings, green tag development in the U.S. can be characterized as being in an ad hoc, "learn by doing" mode.

BEF has been endorsing green power to utilities, government agencies, and businesses since 1998. BEF has completed transactions involving the sale of some 23 MW of green power working with the Bonneville Power Administration (BPA) and other suppliers, and supporting environmental groups. In May 2000, BEF announced its first green tag sale, to the EPA Region 10 office. The CO_2 emissions and other environmental effects of 25 percent of EPA's regional electricity use will be offset with BEF Green Tags.[47]

Table 5-2 provides a partial list of companies in the U.S. that are Green-e certified green tag providers. These providers, particularly Sterling Planet, may be a good source of information regarding selling Green Tags.

[47] Bonneville Environmental Foundation, "Summary Description of BEF's Green Tag Product" October 2000.

Table 5-2. Partial list of Green-e certified TRC providers

Certificate Marketer	Contact website	Product Name	Renewable Resources	Location of Renewable Resources	Residential Price Premiums[a]	Certification
3 Phases Energy Services	http://www.3phases.com/	Green Certificates	New wind	Nationwide	2.0¢/kWh	Green-e
Aquila, Inc.	http://www.thenergyteam.com/	Aquila Green (non-residential only)	New wind	Kansas	N/A	Green-e
Bonneville Environmental Foundation	http://www.greentagsusa.org/	Green Tags	99% new wind, up to 1% new solar	Washington, Oregon, Wyoming	2.0¢/kWh	Green-e
Community Energy	http://www.newwindeenrgy.com/	New Wind Energy	New wind	New York, Pennsylvania, West Virginia	2.5¢/kWh	Green-e
EAD Environmental	http://www.eadenvironmental.com/					
Maine Interfaith Power & Light		Green Tags (supplied by BEF)	99% new wind, up to 1% new solar	Washington, Oregon, Wyoming	2.0¢/kWh	Green-e
Mainstay Energy	http://www.mainstayenergy.com/	Mainstay Rewards	All	Nationwide		Green-e
*Native*Energy	http://www.nativeenergy.com/	*Wind*Builders	New wind	South Dakota	$60-$120 annual membership	

Table 5-2. Continued

*Native*Energy	http://www.nativeenergy.com/	Vermont *Cook*Home (residential only)	New biomass (dairy farm methane) and new wind	Vermont (biomass), South Dakota (wind)	\$6/month or \$60/year	
PG&E National Energy Group	http://www.purewind.net/	PureWind Certificates	New wind	New York	4.0¢/kWh	
Renewable Choice Energy	http://www.renewablechoice.com/	American Wind	New wind	Nationwide	2.5¢/kWh	Green-e
Sterling Planet	http://www.sterlingplanet.com/	Green America	15% geothermal, 5% low-impact hydro, 5% solar (all new)	Nationwide	1.6¢/kWh on average	Green-e
Sun Power Electric Corporation	http://www.sunpower.org/	ReGen (available in New England only)	99% new landfill gas, 1% new solar	Massachusetts, Rhode Island	3.6¢/kWh	Green-e
Waverly Light & Power	http://www.waverlyia.com/tags.htm	Iowa Energy Tags	Wind	Iowa	2.0¢/kWh	
Notes:[a] Large users may be able to negotiate price premiums. This is the price they sell their tags for. Purchase price from generators will be lower. N/A = Not available						

5.2 Facility Heating and Cooling

Facility heating and cooling systems convert the energy stored in wood fuel into a more convenient form of energy for space heating and water heating. Wood-fired burners and boilers offer automated operation, low emissions, and potentially lower costs than conventional alternatives. Wood burners produce heated air that can be used for heating in applications similar to forced-air furnaces. Boilers produce hot water or steam that can be used for facility or district heating, cooling and hot water needs or to produce power in a steam turbine. The basic components of wood boiler systems are the wood receiving/storage area, combustion system, boiler system, ash handling system, and pollution control equipment.

In district heating and cooling systems, several buildings are served from a central plant through a common distribution system. The distribution system can carry forced air, hot water, steam or any combination thereof through pipes to provide a continuous supply and return of heat or chilled water. The aggregation of energy services for multiple buildings can improve reliability, energy efficiency and reduce peak electric demand.

Heat can be generated for district heating systems in a number of ways, including boilers, heat recovery from a combined heat and power plant or industrial processes. Cooling can be accomplished using absorption chillers. Absorption chillers can use heat from a boiler to provide cooling power by evaporating a fluid, often water, in an evaporator, which is then absorbed by a lithium bromide fluid in an absorber. The temperature of the resulting evaporated liquid is lowered through a chemical process called adiabatic cooling. The evaporated liquid cools a fluid that can then be circulated for air conditioning or other cooling needs. The evaporated fluid is then condensed for reuse.

As discussed earlier in this report, two facilities in Colorado are installing wood heating systems.

Biomass heating systems are most cost-effective when used to offset energy used in electric, oil or propane heating systems. This is primarily because the costs of these heat sources are often higher than biomass fuel costs (Table 5-3).

Table 5-3. Comparison of biomass and fossil fuels for heating

Fuel [1]	Unit	Cost, $/unit	Btu/unit	Efficiency	Cost $/MMBtu
Electricity	kWh	0.07	3,412	95%	21.60
Electricity	kWh	0.11	3,412	95%	34.06
Corn	ton	230	16 million	80%	17.97
Heating Oil	gallon	1.8	138,000	80%	16.30
Propane	gallon	1.1	91,000	80%	15.11
Biomass Pellets [2]	ton	185	16.4 million	75%	15.04
Wood Briquettes	ton	160	16.4 million	80%	12.20
Natural Gas	therm	0.73	100,000	80%	9.09
Coal	ton	170	25 million	75%	9.07
Ag Residue Pellets [3]	ton	100	16 million	75%	8.33
Cordwood	cord	130	22 million	75%	7.88
Biomass chips	green ton	40	9 million	75%	5.93

(1) Concept and reference data from Pellet Fuels Institute and HearthNet. All prices are subject to change. Unit Btu's and efficiencies will vary with fuels and appliances. Prices are based on recent market data.
(2) This group of pellets includes wood, cardboard and certain types of paper and agricultural-residues. This premium fuel category has under 2% ash.
(3) This category includes peanut hulls, sunflower hulls and oat hulls. Ash contents are greater than 3%.

Figure 5-1 is a chart of simple payback period versus wood price for four different natural gas prices: $3, 5, 7, and 9 per million Btu. Simple payback period is defined as the incremental capital cost (e.g. wood-fired system – natural gas fired system capital cost), divided by the first year savings. The annual costs include both O&M costs (which are considered fixed, in this analysis), and fuel costs. When gas costs are relatively low (i.e. $3 per MBtu), the wood cost strongly affects the payback period. As the fuel cost increases, the payback period graph begins to flatten out, and becomes less sensitive to wood cost.[48] The current price for natural gas

When natural gas prices are low, it is very difficult for wood to compete, as the annual O&M costs are higher for the wood-fired system than for the gas system. As the price of gas increases, the wood-fired system becomes very inexpensive to operate, relatively, and the payback period becomes shorter.

[48] The data used to prepare this graph are taken from the following report: McNeil Technologies, Inc., *Feasibility Study of a Biomass Energy System for Boulder County Parks Department.* June 2003. Available from the Boulder County Department of Parks and Open Space. The payback figures are based on an incremental capital cost of a wood heating system compared to a natural gas systems of $356,000.

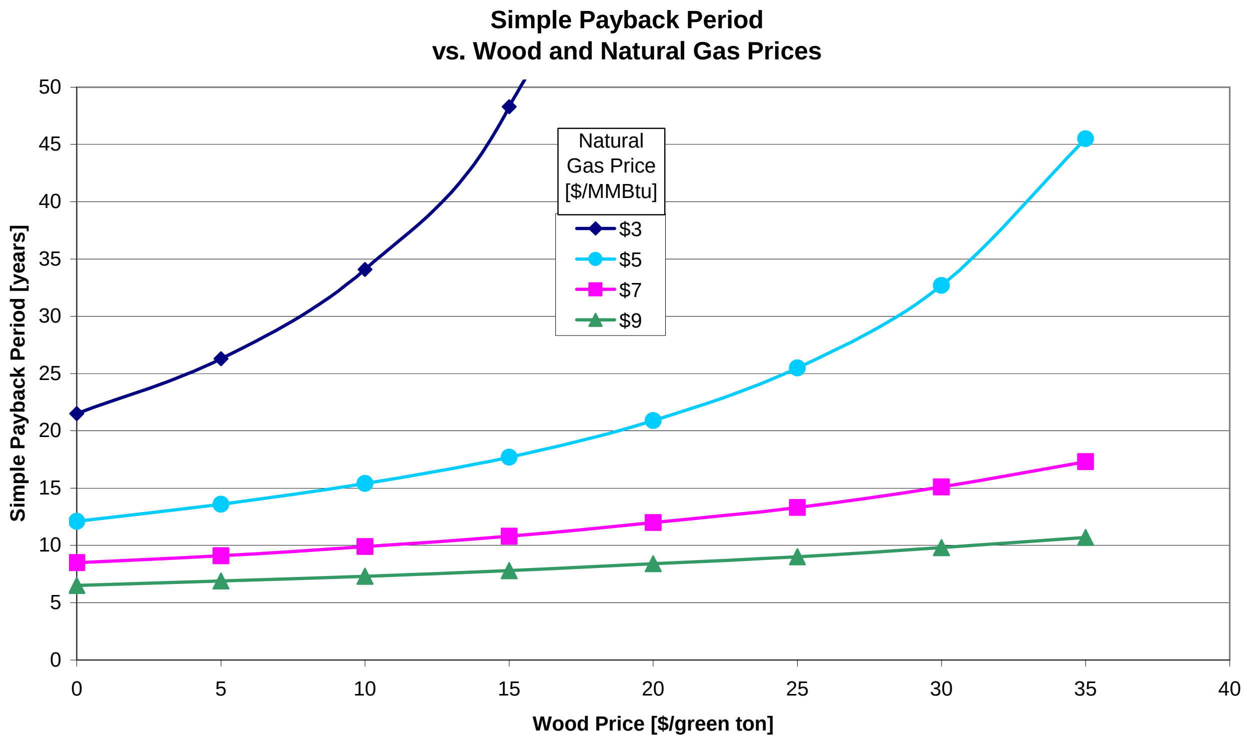

Figure 5-1. Simple payback of biomass wood heating system vs. natural gas

5.3 Potential Biomass Energy Applications for the Front Range

Electricity and heat generation (cogeneration) are the two primary options for biomass utilization. Electricity generated using biomass can be used on-site, with the excess sold to the electric power grid if an economically beneficial power purchase agreement can be negotiated through the local utility or rural electric cooperative. Cofiring the biomass in a coal-fired boiler reduces the amount of coal required and reduces the emissions of pollutants to the environment. This can usually be done with existing boilers with minor equipment modifications. Combustion is often a seasonal use for biomass, as many boiler applications are only required during the winter.

Table 5-4 lists some of the facility types where biomass heating, power generation and cofiring could be a viable option. Table 5-4 is not an exhaustive list of all potential candidate facilities.

Table 5-4. Matrix of selected biomass technology applications

Type of facility	Biomass facility and process heating	Power generation/ CHP	Cofiring
Schools, community centers	✓		
Colleges and universities	✓	✓	
Hospitals	✓	✓	
Government buildings	✓	✓	
Hotels/resorts	✓		
Correctional facilities	✓	✓	
Power plants		✓	✓
Industrial (partial list)			
Wood products	✓	✓	
Cement kilns		✓	✓
Metals manufacturing	✓	✓	
Brick and clay tile	✓	✓	✓
Food processing	✓	✓	

A variety of factors affect whether a facility is a good candidate for biomass heating or power generation. Some of these include:

- Size of heating load and/or power requirements
- Age of heating system (i.e., whether building system is due for replacement or upgrade, or whether system can be integrated into new construction),
- Current heating fuel (i.e., electric, natural gas, propane, oil or coal heating system),
- Current operating and fuel costs,
- Heat distribution system (forced air, water), and
- Management and maintenance staff interest.

Biomass power technologies are particularly suited to locations that have access to low-cost wood or other biomass fuel and where electricity costs are high. Most existing biomass power plants are either on-site or nearby wood products manufacturing facilities, where the biomass resource is readily available at a low cost. The size of most biomass power plants ranges from 10 to as high as 80 MW total. Some of these plants use the majority of the power generated to meet their own needs. Others, such as the Burlington Electric Department biomass plant in Burlington, Vermont, meet community electricity needs. However, siting a biomass power plant on this scale requires an industrial site and access to significant quantities of biomass fuel. Smaller biomass power generation technologies that can serve smaller electricity loads, such as community centers, schools and even residences, are in the development and demonstration stages.

Biomass power generation can be more cost-effective for facilities that have significant heating loads, because heat from the burner or boiler system can also be used for process or facility heating. Producing both heat and power simultaneously is known as combined heat and power, or cogeneration. Electricity generation alone is typically only 15-30 percent efficient. Cogeneration can increase the overall energy efficiency to 70-90 percent.[49]

5.4 Technical Potential for Biomass Power Generation in the Front Range

In this section, we estimate the potential generating capacity that could be produced from the Front Range's biomass resources.

Table 5-5 lists the assumptions used to estimate the technical potential for biomass power generation capacity. Since there are potential constraints on the biomass supply, we assume that small biomass plants are more likely to be deployed rather than a larger centralized plant. We assume that only 75 percent of the total biomass will be available for power generation. The assumption of 75 percent is a conservative estimate of biomass availability in the region. This additional constraint is over and above constraints on availability of forest biomass due to location of forest land to be managed within the Red Zone, and limitation of management to forest land with slopes less than 40 percent. In addition, this constraint is over and above those placed on urban resources by limiting availability to quantities that are currently landfilled, recycled or given away. Using a conservative approach to estimating the biomass power potential takes into account institutional and infrastructure needs that need to be addressed in order to develop a biomass power supply system in the Colorado Front Range, and accounts for the fact that other uses of biomass will be developed.

Table 5-5. Assumptions for estimating biomass power technical potential

Variable	Units	Value
Technology size	MW	5
Technology type	Stoker	
Electrical efficiency	%	14.22
Plant heat rate	Btu/kWh	24,001
Plant capacity factor	%	90
Plant availability factor	%	90
Resource availability factor	%	75

To calculate the potential capacity, we multiplied total biomass generation by the resource availability factor to estimate annual biomass availability. The total biomass heating value was obtained by multiplying available biomass by the fuel higher heating value (HHV) and by 2000 pounds (lb) per ton to obtain British thermal units (Btu) per dry ton. Then the total heating value of the resource was divided by the plant heat rate (24,000 Btu per kilowatt-hour (kWh) or 14 percent conversion efficiency) to estimate total biomass power generation. This value was divided by one million to convert from kWh to GWh of power generation. To estimate installed

[49] Borbely, Anne-Marie. "Combined Heat & Power: Energy Reliability and Supply Enhancement." U. S. Department of Energy Battelle Memorial Institute. 1999.

biomass power capacity, total biomass power generation was divided by the plant capacity factor, availability factor, and the number of hours per year to provide generation capacity in gigawatts (GW). This value was multiplied by 1,000 to provide capacity in megawatts (MW).

Using 75 percent of the biomass resource generated in the Front Range of Colorado could support 47.6 megawatts (MW) of biomass power generation capacity and 337 gigawatt-hours (GWh) of electricity each year (see Table 5-6). Assuming an average household in Colorado uses 600 kWh/month of electricity, the biomass plants could meet the energy needs of approximately 46,000 households.

Table 5-6. Summary of technical biomass power potential in Colorado Front Range

Residue source	Biomass generation (BDT/year)	Available biomass (BDT/year)	HHV (Btu/dry lb)	Potential power generation capacity (MW)	Potential power generation (GWh/year)
Forest biomass	349,379	262,034	8920	27.4	195
Excavator/ Land Clearing	25,867	19,400	8810	2.0	14
Landscaper	126,975	95,231	8810	9.9	70
Lawn & Garden	18,698	14,024	8810	1.5	10
Pallet Mfg	2,780	2,085	9210	0.2	2
Primary mill	5,027	3,770	9210	0.4	3
Secondary mill	17,258	12,943	9210	1.4	10
Commercial tree care	61,380	46,035	8810	4.8	34
Total	607,364	455,523	NA	47.6	337

Note: HHV values from California Energy Commission, internal report

5.4.1 Potential Benefits of Developing Biomass in Colorado[50]

Based on a potential capacity of 47.6 MW that could be developed within the Front Range, we estimate that approximately 221 jobs would be created by this industry. These include jobs at both the plant as well as for the fuel supply infrastructure. We also estimate that the industry would offset about 660 tonnes/day of carbon dioxide emissions from fossil fuels, and contribute approximately $1.4 million per year in taxes. Additional benefits associated with wildfire mitigation are difficult to quantify but include improvement in watershed management, reduced air emissions from wildfires, and dramatic reductions in fire fighting costs including the reduction in risk to human life and habit.

[50] The numbers in this section are calculated using a spreadsheet model developed by the California energy Commission. The model has been modified with inputs for Colorado.

5.5 Economics of Biomass Power

Bio-power is generally an expensive form of electricity. The fuel is often several times more expensive than it's major solid fuel competitor, coal, and the biomass fuel also has a higher moisture content and lower energy content than coal. Further, capital costs for biomass systems are also more expensive than coal units, primarily because coal plants tend to be quite large and thus capture economies of scale not available to bio-power facilities.

For this report we have prepared hypothetical pro forma economic calculations for several sizes of biomass facilities to present a general overview of the delivered cost of electricity. The assumptions used in the model are documented in Appendix H of this report. As presented in Table 5-7 and shown in Figure 5-2, the cost of electricity is expensive but declines with increasing capacity when fuel costs are held constant. Typically the smaller facilities have both higher capital and operating costs. Capital costs are higher on a $/kW basis because manufacturers are afforded economies of scale in the production of the larger components of the installation such as the turbine, boiler, and cooling tower. Fixed operating costs, predominantly personnel costs, are higher for smaller facilities because a minimum number of people are required to run a facility while it is possible to operate a much larger facility with only slightly increased staffing levels.

Table 5-7 Calculated biopower direct combustion levelized electricity costs

Capacity (MW)	Capital Cost ($/kW)	Fuel Consumption (GT/hr.)	"Roadside" Fuel Cost ($/GT)	Fixed Cost ($/kW -yr.)	Variable Cost ($/kWh)	$/kWh
5	$2,400	15.9	$46.5	$94.00	$ 0.003	$0.0976
25	$2,248	55.2	$46.5	$84.35	$ 0.003	$0.0717
50	$2,096	92.9	$46.5	$74.70	$ 0.003	$0.0620

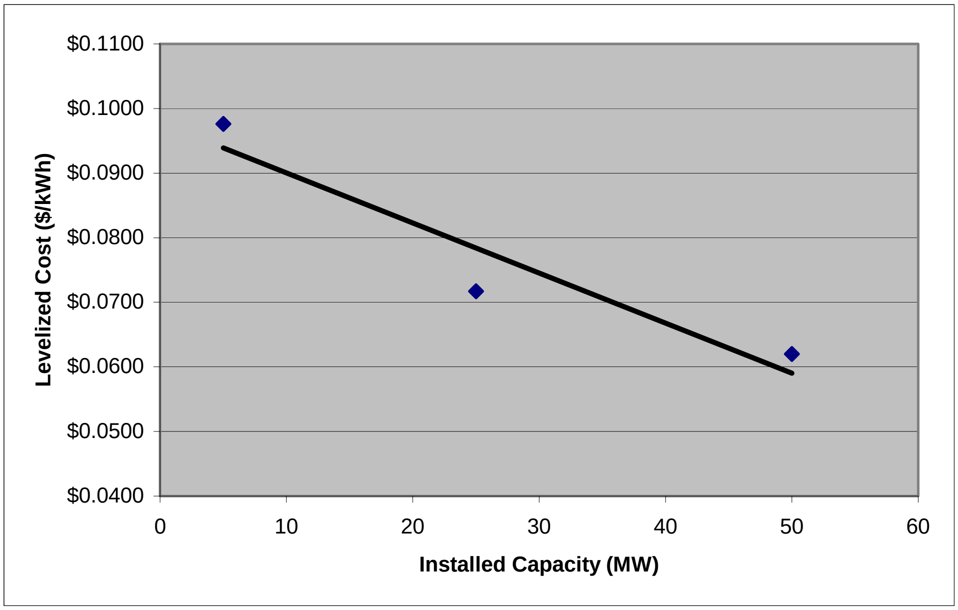

Figure 5-2 Levelized electricity cost as a function of capacity

Because the biomass resource base along the Colorado Front Range is likely to support smaller facilities, it is useful to focus additional attention on the operating costs of a hypothetical 5 MW facility. Figure 5-3 provides the calculated distribution of annual operating costs for a 5 MW direct combustion facility. Fuel costs are the major cost element, representing 55 percent of annual costs. Debt service is also a significant cost, illustrating the relatively high capital costs on a per unit basis. The calculations in the figure assume a fuel cost of $3.00/MMBtu ($53/Bdt). Other costs are the same as those presented in Table 5-7.

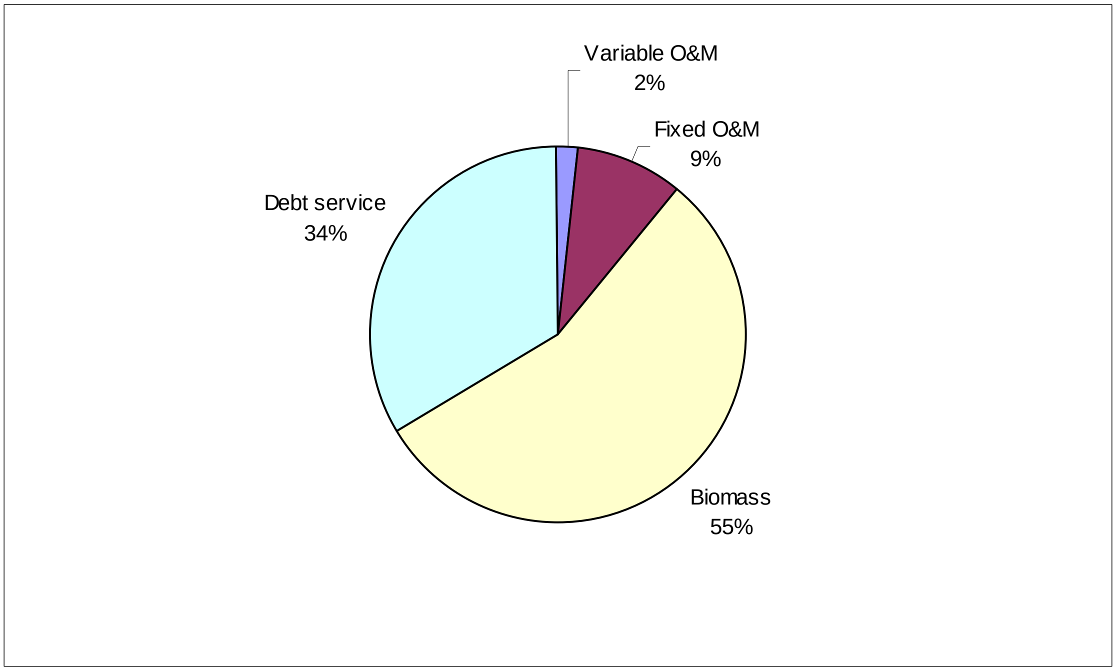

Figure 5-3. Calculated distribution of annual operating costs, 5MW direct combustion

It is clear that for biomass to be a competitive source of electricity, fuel costs need to be significantly reduced. As illustrated in Figure 5-4, the financial model was used to vary the price of fuel within a plausible range of delivered costs, from $1.50/MMBtu to $5.00/MMBtu. In this example, holding all other costs constant, the levelized cost of electricity varies on a constant dollar basis from $0.075 to over $0.15/kWh. For this particular example, if fuel costs are reduced to zero, then the levelized cost is slightly under $0.04/kWh.

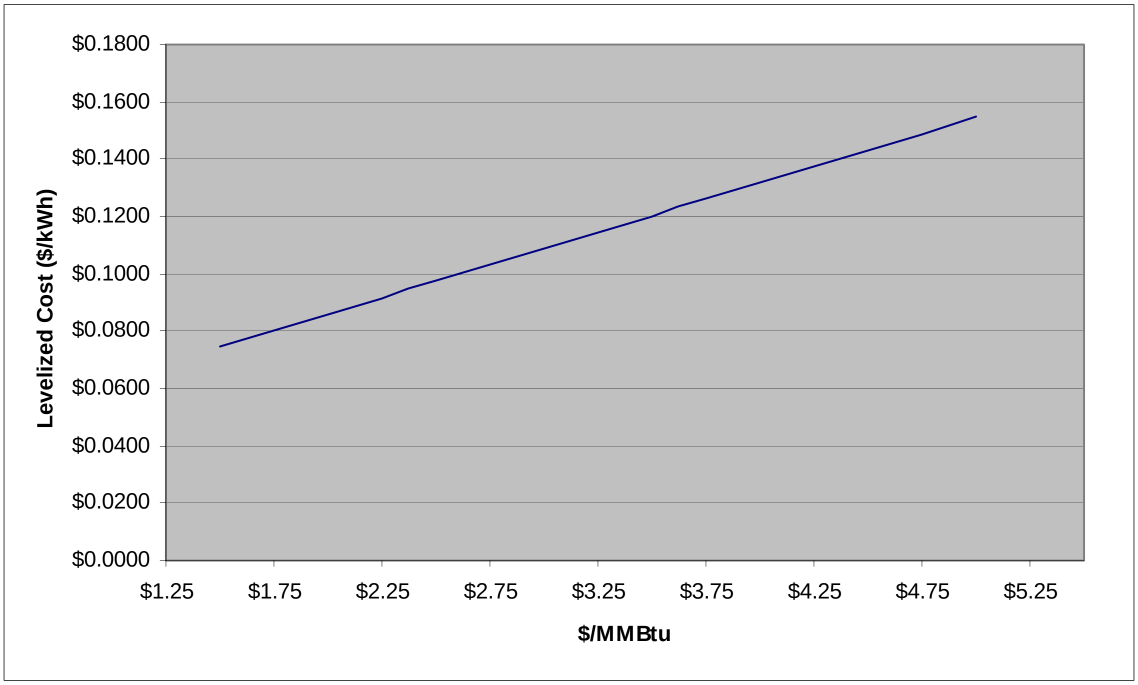

Figure 5-4. Levelized cost and cost of fuel, 5MW biopower facility

5.6 Barriers to Bioenergy Development in Colorado

There are several challenges to developing biomass energy in Colorado. The extent to which the biomass resource potential will be converted for electricity generation or thermal energy depends on addressing and resolving the barriers identified below. These barriers have been categorized into fuel, economic, institutional, technology and environmental categories. [51]

5.6.1 Feedstock/Fuel Barriers

The key barrier to the sustainability of biomass power generation in Colorado is the current limitation of biomass fuel availability, both in terms of cost and supply. It is well-understood that biomass is a low-density fuel with high moisture content and relatively low Btu content (see Table 5-8). The table shows the challenges facing biomass fuel when compared to traditional fossil fuel. Biomass has a low heating value, high moisture content and high cost when compared to coal.

[51] This section is adapted from and draws heavily from the following paper prepared by Valentino Tiangco of the California Energy Commission: *Technical, Economic and Environmental Issues for Sustainable Generation of Biomass Power in California*. Valentino Tiangco et. al, undated. Available from Mr. Tiangco at the CEC.

Table 5-8 Comparative fuel properties[52]

Fuel Parameter	Units	Western Coal	Western Forest Biomass	Dry Wood Pellets	Municipal Solid Waste	No. 2 Fuel Oil
Moisture Content	**percent**	**3**	**55**	**10**	**30**	**0**
As-fired heating value	**Btu/wet pound**	**9,132**	**5,418**	**8,127**	**4,500**	**19,430**
Fuel bulk density	**lb/ft^3**	**45**	**22**	**35**	**12**	**53.9**
As-fired energy density	**$kBtu/ft^3$**	**421**	**119**	**284**	**54**	**1,047**
Fuel feed rates	**ft^3/MMBtu**	**2.4**	**8.4**	**3.5**	**18.5**	**1.0**
Approximate delivered cost	**$/MMBtu**	**1.33**	**~3.00**	**9.84**	**(4.44)**	**10.51**

Biomass harvesting can include a variety of processes, including felling, chipping, skidding, baling or cubing of residue, and bundling of large trees or logs for transport to power plants. Harvesting and collection equipment and techniques that are available are inefficient, especially forest biomass. Development of new densification systems could help reduce the costs of collecting and transporting biomass. In Colorado, where forest health is a major issue, biomass supply associated with fuels reduction activities is very expensive. The cost of felling, skidding, chipping and transporting a tree is too high for current economic conditions. Without either dramatic technological advances to reduce the cost or intervention by public agencies to offset societal costs associated with fuel reduction, forest biomass will continue to be an expensive resource, especially when compared to coal. Comparisons to natural gas are more favorable given the current high price of natural gas.

5.6.2 Economic Barriers

Fuel costs are the dominant portion of the levelized cost for biopower. The levelized costs associated with mid or large-scale biomass power generation, while commercially proven, are on the high side of current power generation technologies. Indeed, the relatively low conversion efficiency, coupled with limited economies of scale tends to marginalize the economic potential of biopower. Virtually all biomass fuels have alternative market uses, and their prices will reflect those alternative uses, as well as the scarcity of particular biomass products. The levelized cost for a biomass power plant using today's technology is in the range of $0.08 – 0.11/kWh at a feedstock cost of $3.00/MMBtu (about $50/bone dry ton).

Production Costs. The high cost of harvesting, raking, baling, collecting, processing, and transporting many biomass fuels severely limits the availability of these resources for energy generation. Much of this cost is due to high labor expenses necessary for collecting the residue. The lack of organizational infrastructure to bring biomass fuels to market has a major bearing on the cost

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[52] Sampson et. al, Western Forest Health and Biomass Energy Potential, a report to the Oregon Department of Energy, April 2001

of biomass fuels. For O&M costs at the plant, there is not a linear reduction in the number of staff required for a 50 MW plant and a 5 MW plant. In some cases, the same number of people required to run a 5 MW plant could run a 20 MW or even 50 MW plant because of the high degree of automation and sophisticated computer controls at these plants. This leads to higher operating costs on a $/kWh basis for the small plant because the fixed costs are spread out over less total energy produced by the facility.

Capital Costs. There is a high investment cost on new or improved biomass collection machinery, often on the order of several hundred thousand dollars per piece of equipment. Capital costs for biomass combustion facilities are very high, typically ranging from $1500/kW to $2500/kW. Capital costs increase as system size decreases. In contrast, capital costs for a modern state-of-the-art natural gas-fired combined cycle plant range from $600/kW to $800/kW. There have been some reports that biomass vendors are now selling power systems for less than $1,000 per kW. This cost is for the basic unit only, and it is likely that additional site preparation, engineering, permitting and interconnection fees will drive this price higher.[53]

Tax Credits. The federal government could speed the development of new plants by expanding the Section 45 tax credit to include all biomass sources. The Section 45 tax credit, passed in 1992, provides 1.5¢/kWh support (adjusted for inflation the credit is now 1.8¢/kWh) to wind and closed loop biomass technologies. On the wind side, generators used the credit to restart the growth of an industry that had been virtually stagnant since 1987. By 1994, the effect of the credit and further technical innovation jump started wind development, and the industry in 2003 is clearly benefiting from the credit. In the case of biomass, the definition of closed loop biomass was so restrictive as to eliminate all waste forestry, agricultural and urban fuels now used by the industry. As a consequence, no biomass facility owner has ever been able to collect any payments under the closed loop biomass tax credit. The problem is that the credit applies only to "closed loop biomass," which refers to agricultural products grown exclusively for combustion in a power plant. There has not been such an undertaking in the U.S. in the eleven-year life of the credit, as economics simply will not support it, even with the credit.

There are provisions in the current Energy Bill before the Congress that would expand the credit to all biomass facilities. This would help overcome the price disparity between the generation costs and the cost of wholesale power. Another potential credit, contained in the President's Healthy Forest Initiative and the Energy Bill, would provide a $20/ton biomass fuel credit to generators. The status of these credits is uncertain in the legislation at this time.

Fuel Transportation. A large cost component in biomass residue production is transportation. Transportation rates are nonlinear with respect to distance and a larger facility requires a larger biomass collection radius to guarantee sufficient residue supplies. A typical 25 to 30 megawatt biomass plant might use 200,000 tons of residue per year. With an average trip of 10 to 15 miles, the average transportation cost would be between $6 to $7.25 per bone dry ton. Alternatively, the cost

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[53] Itasca Power from Minnesota and Chiptec Systems of Vermont are both reporting system capital costs below $1,000 per kW for small-scale systems (about 5 MW). The final "all in" price of their systems have not been verified. Chiptec has built a plant in Iowa and one in Wisconsin, and Itasca has a plant in Prince Edward Island, Canada.

range for hauling residue from a roadside between 1 and 100 miles would be between $5.40 to $14.80 per bone dry ton, with rapidly decreasing costs on a per-mile basis due to high fixed costs. Distances of up to 100 miles are not uncommon with costs of $20 per bone dry ton.

Costs of Water Usage Systems. The cost of construction and operation of a closed-cycle cooling system is substantially higher than a once-through cooling system. A zero-discharge system is even more costly. What makes these alternative systems necessary are the lack of water resources and environmental restrictions placed on the effluent water stream.

5.6.3 Institutional

Availability of a low-cost sustainable feedstock is a critical determinant for the successful operation of a biomass facility. Feedstock acquisition is generally limited to a radius of 75-100 miles or less from the power plant, thereby often requiring smaller unit sizes. Smaller sized units in turn are less efficient, have higher capital costs on a $ per kW basis, and higher operating costs due to fixed costs associated with O&M of the facility. The radius is limited because the transportation cost becomes increasingly high for each additional mile from the resource to power plant.

Obtaining a biomass fuel supply contract that is satisfactory to both lenders and power plant investors is an institutional barrier that is related to the availability of the supply. Typically lenders and plant owners prefer a longer-term contract, on the order of 5-10 years, while a supplier tends to prefer a year-to-year or even month-to-month arrangement to allow for the vagaries of the fuel supply market. A sufficient diversity in feedstock supply sources must be demonstrated in order to satisfy lender, investor and operator concerns in the absence of a long-term fuel supply contract.

Given the current state of forest health and fire suppression debate, there is considerable pressure to obtain material from national forests. One major issue that the project developer, fuel supplier, and lender have to address is the variability in the amount of resource generated from Federal lands, principally national forests administered by the U.S. Forest Service. The planning timeframe for forest management projects on federal land, variable staffing support for forest management and shifting forest management priorities reduce the reliability of supplies from federal land. In many cases, this requires fuel supply planners to size biomass plants to meet the most conservative estimates of biomass supplies from federal land.

Siting a biomass power plant has some of the same barriers associated with any industrial facility; noise, dust or particulate matter from vehicle traffic, emissions impacts in non-attainment areas or special areas such as locations near National Parks and National Monuments, local opinion and acceptance, and compatibility with adjacent land uses. Each of these barriers can be addressed during a plant pre-feasibility study, and later during a site engineering and environmental assessment.

Interconnection requirements to the electric utility grid can be a technical barrier for biomass power generation, especially for mid-size power systems since the engineering and equipment costs for interconnecting a mid-size system are comparable to those for a large industrial or stand-alone biomass power plant. Interconnection policies and requirements can vary from utility to utility, and some utilities may not have any recent practical experience connecting a small system to their grid.

With regard to green power and green tag markets, the fact that forest biomass is not considered as an eligible resource to produce tradable renewable credits limits the market potential for biomass power. If the new Aquila project can successfully address this issue, it would represent a major step forward in the ability of forest biomass to participate in the green power market.

A final institutional barrier is the distrust between the environmental community, land managers, and the forest products industry. Some environmental groups oppose forest thinning and using the resulting biomass for power. Their concern is that a biomass power plant will drive thinning and lead to pressure on land managers to increase access to biomass in the forest. The environmental community does not speak with one voice in this regard, as there are many groups that support thinning and small-scale biomass power.

5.6.4 Technical Barriers

The use of biomass fuel to produce energy has been mostly limited to direct combustion. The main technologies, stokers and CFBs, are considered commercial but inefficient in terms of converting energy in the fuel to useful electrical energy. The development of cost-effective gasification systems, especially integrated with advanced-power generation (e.g., gas turbines and/or fuel cells) is a major issue for all size ranges. For the conservative electric power industry, many more years of operational experience with units such as the McNeil Generating Station are required before the technology will be widely adopted.[54] Small units targeted at distributed or minigrid applications have only been recently placed in demonstration trials and commercial application isn't expected for several years.[55] The US DOE has a commitment to the biomass syngas platform to enhance its economic viability. Issues associated with gas cleanup (removal of contaminants such as tar, particulates, alkali, ammonia, chlorine, and/or sulfur) are the subject of much current research.[56] The primary technical issues facing biomass power are moisture content, fuel storage, ash deposition, low conversion efficiencies, potential for slagging in the boiler, and NOx control.

All of the biomass direct combustion technologies have relatively low conversion efficiencies when compared to fossil fuel generation technologies. Biomass technologies typically have efficiencies on the order of 14 to 24 percent. This is about half the efficiency of natural gas fueled combined cycle facilities (40-45 percent). The low thermal efficiencies associated with biomass fuel combustion are primarily a result of the direct combustion technologies and the biomass fuel properties.

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[54] US DOE Biopower Program. On-line: http://www.eere.energy.gov/biopower/projects/ia_pr_gas_VT.htm

[55] US DOE Biopower Program. On-line http://www.eere.energy.gov/biopower/projects/ia_pr_gas_CO.htm

[56] US Department of Energy, Office of Energy Efficiency and Renewable Energy, Office of the Biomass Program, Multiyear Plan 2003-2008, http://www.bioproducts-bioenergy.gov/pdfs/MultiyearPlan2003-2008.pdf

Nevertheless, biomass conversion technologies are commercially available, reliable, and have been meeting performance objectives for many years. The barriers discussed in this section are simply issues to be considered during the design and operation of the system and are not show stoppers.

5.6.5 Environmental

Biomass power conversion is one environmentally preferable method for addressing myriad issues associated with disposal or treatment of multiple resource streams. Biomass energy conversion is a beneficial alternative to landfill disposal of biomass, open burning, or forest fuels accumulation contributing to unacceptable wildfire risks.

Environmental considerations associated with biomass energy conversion fall into three main categories: (1) emissions from the conversion process itself, (2) fuel supply collection impacts; and (3) avoided emissions. The first category represents the emissions associated with combustion or gasification processes and are dominated by air emissions. Under the second category, wildlife habitats can be affected when forest slash is removed from its original site. The third category is based on offsets in emissions from fossil fueled generators.

6. SUMMARY AND RECOMMENDATIONS

This report conducted an overall assessment of the potential to develop biomass energy opportunities for the Colorado Front Range. This section contains conclusions and recommendations.

6.1 Conclusions

6.1.1 Community Outreach

McNeil and the CSFS organized and hosted a public meeting in Nederland, Colorado in August, 2002. The meeting was successful in generating local interest in biomass topics and provided technical information to community stakeholders. The meeting led directly to two biomass projects being implemented. The first is the heating and small power generation system at the Nederland Community Center, and the second is the facility heating system for Boulder County. The public meeting will serve as a template for other interested communities in the future.

6.1.2 Utility Customer Survey

McNeil staff conducted a limited telephone survey of households living in Red Zone counties. The purpose of the survey was to determine public perceptions of forest restoration activities and biomass power, and to asses utility customer willingness to pay extra for biomass power if their utility offered them a choice to do so. Overall, 62 percent of the respondents said that they would be willing to pay more to purchase biomass power from their utility. The survey also found that 45 percent of respondents are willing to pay an extra $10/month or more to purchase biomass power if their utility were to give them an option to do so. It must be noted that actual participation rates would most likely be lower than these numbers indicate. Many other green power surveys have found that when it actually comes time to sign up, fewer people actually do so then the initial survey results indicate. Nevertheless, it is apparent that there is a potential market for forest biomass power in Colorado.

6.1.3 Federal Agency Renewable Electricity Purchases

The Federal goal of obtaining 2.5 percent of total federal electricity usage from renewables will continue to drive agency purchases of green power. As shown in Table 6-1, Federal agencies are presently purchasing approximately 284 GWh of electricity. Purchases by the Air Force represent over half of total purchases and combined purchases by the military are 64 percent of the total. The USDA, which encompasses the USFS, accounts for just 2 percent of total purchases. It is clear there is potential for the USFS to direct its purchasing power towards biomass, either from stand-alone facilities or from co-firing installations.

Table 6-1. Federal Purchases of Renewable Power, 2003[57]

Agency	GWh	%
Air Force	147.2	52%
EPA	27.4	10%
DOE	19.5	7%
Army	19	7%
Navy	16.7	6%
GSA	16.6	6%
Denver Wind Initiative	11	4%
NASA	10	4%
GSA (multi-agency)	5.6	2%
World Bank	5.5	2%
USDA	4.8	2%
BPA	0.6	0%
Total	283.9	

6.1.4 Biomass Fuel Supply

The wood biomass resource potential in the Front Range is an estimated 607,364 bdt per year. Current biomass generation from all sources is an estimated 367,172 bdt per year. The gap between potential and current biomass generation is primarily due to a lack of development of the forest biomass resource. Current generation of forest biomass is an estimated 109,187 bdt per year, compared to potential biomass generation of 349,379 bdt per year if 5 percent of forest land in the Red Zone portion of Front Range counties (with slopes less than 40 percent) were managed annually to reduce fuels. Fuels reduction budgets are on the rise. Nonetheless, limitations on fuels treatment budgets and a lack of markets for small diameter materials still restrain the development of forest biomass resources. Despite having authority to enter into long term stewardship contracts, the USFS does not have the budget to implement the level of fuel mitigation work that many believe is required to reduce the threat in the Red Zone. Agencies, however, are increasingly beginning to coordinate planning efforts and develop multi-year strategies to improve the effectiveness and coverage of fuels reduction activities. A biomass power plant is not likely to be built unless the required biomass supply is reasonably stable and available to the plant. One such interagency partnership is the Front Range Fuel Treatment Partnership, which is coordinating fuels reduction efforts in the region and can serve as a model for other regions throughout the western U.S.

6.1.5 Biomass Energy Potential

Biomass thermal applications (i.e., space, water, and process loads) represent perhaps the best opportunity in the near term, primarily because the scale and economics are favorable for development. Within the thermal applications niche, space heating of public facilities is of

[57] Data derived from presentation by Chandra Shah, National Renewable Energy Laboratory, “Renewable Energy Certificates”, Energy 2003, Orlando, FL.

particular interest. Tying the state's "*Rebuild Colorado*" program, particularly the renewable energy criteria for high performance buildings, to biomass resources would be an important step towards gaining market entry for new biomass heating technologies. Importantly, air emissions considerations are addressed with emerging technologies, allowing for siting of biomass combustion systems in air management regions with strict regulations.

Conservatively, we estimate that approximately 48MW of biomass capacity could be developed along the Front Range. This is 337 GWh of energy potential on an annual, sustainable basis or far more than the Federal agencies presently purchase in Colorado alone. Because of seasonal fluctuations of fuel supply levels and dispersed nature of the resource, the potential capacity lends itself to the need for multiple, small-scale plants in the state. No single outlet or application will be suitable to consume the material

Biomass power will face primarily economic and institutional challenges, as the fuel supply is available for a small plant. Technical and environmental barriers are not showstoppers Utilities must enter into a "fair" long-term power purchase agreements to both provide confidence and a desirable rate of return to project developers and investors. Concurrently, Federal agencies need to establish long term thinning contracts to firm up reliable supply so that a potential biomass plant can obtain power purchase agreement and financing from investors. Tax credits will help, but must not be relied upon. Tax credits should be viewed as "icing" for an already baked cake. The developing market for green tags and certification will be beneficial to biomass development in general. While certain biomass power is eligible as green power, bio-power derived from forest thinnings is not presently viable. Finally, the Aquila program can serve as model for other utilities in the state.

One distinct exception to the small-scale observation is the opportunity presented for co-firing at the large coal-fired plants in Colorado. There are no general technical barriers but each plant may have unique characteristics that would be a challenge for the economic feasibility of biomass co-fire.

Presently bio-power is relatively expensive when compared to wind and fossil fuels, especially for small-scale technologies. The social benefits are difficult to capture in the "value" proposition for biomass, particularly for a private developer. The USFS and the State of Colorado need to continue to explore methods to effectively recognize the social benefits of biomass utilization.

The production tax credit available to wind and closed loop biomass helps to make wind more economically attractive. To date, no firm has claimed the Section 45 tax credit for closed loop biomass. Extension of the tax benefit to "open loop" biomass, presently being considered in the US Congress, would be extremely beneficial to the development of biomass power. Similar consideration should be extended to the thermal applications from biomass.

6.2 Recommendations

Several recommendations can be drawn from this work effort.

6.2.1 Education and Outreach

Biomass energy stakeholders should continue to conduct conferences, workshops and public meetings organized around biomass energy and the link to hazardous fuels reduction efforts. Meetings can be organized around the following subjects areas and target audiences:

1. Conduct a “Biomass 101” workshop for the general public. If the Aquila green tag certification project moves forward, this type of conference will help educate consumers about biomass energy, green power and provide them information as to how they can purchase green tags.
2. Continue implementing technical conferences aimed at industry experts to facilitate knowledge exchange, networking and continued dialog amongst those interested in the nascent biomass energy industry.
3. Provide targeted outreach to energy facility managers at public buildings such as schools; state, local, and federal government facilities; prisons; hospitals and ski areas. Goal will be to provide information on biomass heating technology to facility managers.
4. Work to develop a link to the DOE’s Energy Smart Schools Program and provide information on biomass facility heating for schools.
5. Conduct public tours of the Nederland and Boulder facilities when these become operational.
6. Facilitate continued dialog between land management agencies, forest products industry, utilities and environmental groups. The forest health/biomass energy barriers conference being planned for early next winter is an example of this type of meeting.
7. Organize community meetings similar to those held recently in Nederland, Leadville, Dillon and Durango. Coordinate these with local stakeholder groups.
8. Incorporate biomass technologies within the Leadership in Energy and Environmental Design (LEED) System to help provide a foundation for architects, planners, and purchasing agents to include biomass systems in their design process (biomass is not presently a recognized renewable source in the LEED program). The LEED System is a voluntary, consensus-based national standard for developing high-performance, sustainable buildings. Members of the U.S. Green Building Council representing all segments of the building industry developed LEED and continue to contribute to its evolution. Please see http://www.usgbc.org/LEED/LEED_main.asp for information.

6.2.2 Public policy actions

Biomass energy stakeholders should continue to work together to promote public policies and projects that will increase biomass energy deployment. Stakeholders should continue to monitor any RPS legislation that is introduced during the next legislative session. Biomass energy stakeholders should review the definition of biomass energy and ensure that it is acceptable.

Before its defeat earlier this year, the final version of last session's RPS bill (House Bill 03-1295) heavily favored wind energy. The bill stipulated that the capacity of a renewable project is measured based on its nameplate capacity value. For this reason, the full contribution of biomass power is discounted when compared to other technologies. A 5 MW biomass power plant would produce approximately 35 GWh/year, assuming a plant factor of 81 percent (see Table 6-2). On average, the same 5MW of wind power would produce 15 GWh/year, or roughly half as much energy as a 5 MW biomass plant.

In the bill, solar is given a multiplier of 3 when evaluating nameplate capacity. Thus a 5MW concentrating solar power plant would be rated as 15MW. Annual electricity production for the CSP would yield 29 GWh/year without storage and 65 GWH/year with storage, assuming a plant factor of 22 percent and 65 percent, respectively. Biomass energy proponents have a strong argument that biomass technology should be assigned a multiplier equal to that of solar.

Table 6-2 Annual Energy Output for Various Renewable Energy Technologies[58]

Category	Units	Wind	CSP w/o storage	CSP w/ Storage	Biomass
Capacity	kW	5,000	15,000	15,000	5,000
Capacity Factor	%	35%	22%	55%	90%
Availability	%	95%	90%	90%	90%
Plant Factor	%	33%	22%	50%	81%
Annual Generation	GWh	15	29	65	35

The 4.5 cent/kWh cost cap placed on renewables in the bill is likely to be too low given the present price trends of natural gas. A higher cap would assist biomass in competing with wind under the RPS legislation.

6.2.3 Biomass fuel supply

The USFS and other landowners should continue to work to implement hazardous fuel reduction projects where they are needed throughout the Front Range. For a biomass fuel supply infrastructure to develop, agencies and landowners must be willing and have the budget to enter into long term stewardship contracts for thinning. This would provide some measure of assurance to a prospective biomass energy facility develop that a long- term fuel supply contract could be obtained.

[58] CSP refers to concentrating solar power, in this case a parabolic trough. The biomass calculation is for a 5MW combustion system.

A biomass energy plant will not be able to pay for the full costs of biomass generated from forest thinning and still be able to produce electricity at a price that is competitive in today's wholesale power markets. Either the cost of fuel and/or power generation must be reduced, or the selling price of electricity must be increased. In California, most biomass plants typically pay for transportation only. If the production tax credit and biomass fuel credit survive in the federal Energy Bill, it will help with the economics of a potential facility. Land management agencies and the public must recognize that there are multiple beneficiaries of fire mitigation work (e.g. water management agencies, recreation, tourism, homeowners, hunters/fishers, general public). The concept of cost shifting should be explored further – how can the costs of thinning be spread out over the largest number of beneficiaries? The proposed fuel supply credit is intended to accomplish this objective.

6.2.4 Green power marketing

Biomass energy proponents should encourage existing green power programs operating in the state to include biomass energy in their portfolio mix. Also, interested agencies should fully support Aquila's efforts to develop their forest biomass green tag program. If this program can be successfully established, it could help overcome some of the economic challenges of biomass energy as well as serve as a model for the entire western U.S. The green tags could also be marketed nationally. If certified TRCs from forest biomass become available, federal agencies in the Front Range could be approached to purchase the tags. The USFS, BLM, DOE, DOD, EPA, National Park Service and others could help meet the federal 2.5 percent renewable goal, and simultaneously support the development of a market outlet for forest biomass.

6.2.5 Electric utility efforts

Biomass proponents should work with the state's electric utilities to encourage their support for the implementation of biomass distributed generation projects. State outreach efforts to utilities could be coordinated around the following topics:

- Conduct a study of the economic and electrical system benefits that utilities may realize through the development of distributed generation at strategic locations within their service area.
- Evaluate whether there are any strategic locations or facilities that could install a small biomass power plant. Most of the time, the plant would operate as a normal power plant. However, in the case of an emergency, the strategic facility would have back-up power that could allow its operations to continue in the event of a major power outage or other fuel supply disruption.
- Document, evaluate and attempt to standardize utility interconnection requirements for small- to medium-sized generators of biomass energy in Colorado.
- Encourage Xcel and Tri-state G&T to include electricity produced from biomass as a new supply resource in their green power programs.

Appendix A. Workshop Materials and Attendees

Biomass to energy and forest management workshops were held in Nederland in August and October of 2002. This appendix includes the meeting agendas, minutes, and other materials, including a presentation from Scott Haase.

Biomass Invitation

August 15, 2002

Dear Interested Party:

We are writing to invite you to attend an information session and tour regarding the following subjects:

- Biomass for energy production and use
- Small diameter marketing and utilization
- Forest restoration/wildfire mitigation projects

This meeting is being sponsored by the Governor's Office of Energy Management and Conservation, USDA – Forest Service, CSFS and the Nederland Committee for Forestry and Wildfire Mitigation.

The purpose of this get together is to introduce stakeholders, community leaders and other interested parties about the potential use of biomass and small diameter material from forest restoration and fuel reduction projects. The information session will concentrate on biomass for energy production and use. The afternoon will be spent touring the Winiger Ridge Ecosystem Management Project near Nederland.

Over the last several years, there has been a tremendous effort involving these issues – particularly as they relate to the Colorado *Red Zone Assessment*, forest health concerns and projects designed to reduce wildfire hazard in the wildland-urban interface. One of the key challenges is how to utilize the vast amount of material generated from restoration and mitigation projects. This meeting represents the initial step in bringing this information and potential projects to the community level.

We look forward to seeing you at the session and tour. Please RSVP via e-mail or feel free to contact me at 303-273-0071 for additional information.

- WHEN: Friday August 30 9:00 a.m. – 4:00 p.m.
- WHERE: Nederland Community Center (Located one mile North of Nederland on the Peak to Peak Highway/CO 72
- NOTE: Lunches will be provided

Sincerely,

Scott Haase
Program Manager, McNeil Technologies, Inc.

Agenda for Nederland Bioenergy/Forest Management Meeting

Date/Time: August 30, 2002

Location: Nederland Community Center (Approx. 1 Mile North of Nederland on Colorado Highway 72)

Purpose: To provide preliminary information on the potential for a biomass energy demonstration project to be developed in or near Nederland. The project would use biomass from on-going forest health/fire mitigation efforts being conducted in the surrounding region.

Sponsors: U.S. Forest Service; CSFS; Governor's Office of Energy Management and Conservation; Nederland Committee on Forest Management and Fire Mitigation

Agenda

9:00	Welcome and overview of the day	*Ed Lewis, Deputy Director* Governor's Office of Energy Management and Conservation
9:15	Fire ecology – historical and current situation	*Dr. Merrill Kaufmann, Research Forest Ecologist* U.S. Forest Service
9:45	Economics and markets for forest biomass	*Dr. Kurt Mackes, Assistant Professor* Colorado State University/CSFS
10:15	Break	
10:30	Bioenergy technologies – applications, costs	*Scott Haase, Program Manager* McNeil Technologies
11:00	Bioenergy technologies from Europe	*Dan Len, Small Diameter Utilization Program* U.S. Forest Service
11:30	Discussion, next steps, potential funding	*Gary Sanfacon, Facilitator* Peak to Peak Healthy Communities Project
12:45 – 4:00	Field Trip	*Christine Walsh, District Ranger* U.S. Forest Service *Craig Jones, Interagency Project Coordinator* Winiger Ridge Project, Colorado State Forest Service

The group will tour several recent fire sites as well as on-going forest restoration and fire mitigation projects. Sites that will be visited include the Black Tiger fire, the Winiger ridge project and the Walker Ranch fire.

4:00 Adjourn

8-30 Meeting Notes

BIOENERGY

- use Dan Len and Scott Haase's recommendations
- small, mobile, temporary better for this area
- area/system analysis needed
- interconnection agreements needed
- perspective – comparisons of cost, pollution, material destination, etc. should include all the real and longterm costs
- need to fill in the cost differences to make program economically viable
- need favorable socio-political environment
- parallel processes/phases – action with planning
- (consider pellet plant) (Scott H. said economic environment not right yet for it)
- TASK GROUP
    - Linda
    - BCFM Eric Phillips
    - Ned FMC members
    - CSFS Craig Jones
    - Elaine Hughs (office of Kurt Mackes)
    - Clear Creek and Gilpin County Commissioners
    - Boulder County rep
    - USFS rep, Christine Walsh
    - Scott Haase (biomass expert)
    - Hillary Collins

FOREST MANAGEMENT PLANS

- should include plans for use and transportation
- ensuring supply – catch up period then project sustainability
- longer and larger contracts
- diverse sources
- a matter of scale
- CURRENT PLAN STATUS
    - USFS – Sugarloaf area plan overlaps NE part of our area and is getting ready for NEPA putting mitigation action within a couple years. Plan including the rest of our area not yet active, but will hopefully get looked at soon. The eventual creation of this plan would benefit from other plans being already in existence.
    - Boulder County – Caribou currently in public process, Mud Lake about 6 months later, Reynolds-Rogers plan exists, some mitigation work already in progress at other locations in the county. Their efforts would be facilitated by the grouping of willing private landowners/associations. Need to address the rights of way on county roads.
    - Town of Nederland – no plan in effect

- CDOT – unknown, usually responsive to requests for tree clearing.
- TASK GROUP
  - Ned FMC members
  - Craig Jones, CSFS
  - Eric Phillips, BCFM

Peak to Peak BioEnergy Task Force

Minutes from Organizational and Planning meeting on October 31, 2002

This first "brainstorming" session took place on Thursday, October 31, 2002 at the USFS Boulder RD from approximately 10:00 am to 12:00 noon.

The next scheduled task force meeting will be on Wednesday, December 11, 2002 from 10:00am to 12:00 noon. Location TBA.

Members Present (no particular order):

- Craig Jones, CSFS Boulder
- Dan Len, USFS Ft Collins
- Amy Krommes (for Christine Walsh), USFS Boulder RD
- Elaine Hughes, CSU/CSFS Ft Collins
- Kurt Mackes, CSU/CSFS Ft Collins
- Tim Rooney, McNeil Tech Denver
- Eric Douglas, Gilpin Co
- Matt Ringer, NREL Golden
- Scott Bruntjen, Mayor of Nederland
- Eric Phillips, Boulder County
- Laurelyn Parcell Sayah, Nederland Community Fire Mitigation
- Linda Smith, Governors Ofc for Energy Mgt/Consv

<u>1. Introductions</u>:

Craig Jones started the meeting by asking those present to introduce themselves and to describe what their interests were relative to this BioEnergy Task Force.

<u>2. Goals and Objectives</u>:

There were several short and long term goals that were discussed.

<u>Short Term</u>:

What is our resource base? Before we can move forward with any BioEnergy projects we need to do a resource assessment. How much wood is available now and how much will be available over the next 2 – 5 years? What is the reality volume for a sustainable/consistent level of biomass?

Tim Rooney from McNeil Technologies is conducting a broad level assessment across the Front Range. He is obtaining data from NEPA approved projects that are planned (all ownerships) and projects that may or may not happen. McNeil has a heating and small scale power interest/focus and are also conducting technology assessments.

Elaine Hughes from CSU is conducting a finer scale assessment for the Winiger Ridge Pilot Project and also in cooperation with the USFS for the Front Range Initiative that is currently being addressed. CSU/CSFS's interest is in small diameter wood utilization and investigating markets not currently addressed in the Front Range.

Amy Krommes, USFS Boulder RD, states that they are planning on cutting 2000 acres per year over the next 2 – 5 years within the district for fuels reduction purposes – a ball park figure. She also emphasizes that one of the district goals is to cut for fuels reduction, and that they are not managing for sustainable commercial timber.

Scott Bruntjen, Mayor of Nederland, would like to see a sustainable/full cycle system (i.e. Biomax 15 Unit) using biomass installed in the Nederland Community Center/School within the next year for the purpose of heating. They are in the process of updating the community center/school and would like to see this technology implemented. There is also interest in acquiring a unit for the Eldora Ski area as well.

Long Term:

Over the long term and short term there will need to be education about these projects brought to the environmental groups. There will also need to be community planning to accomplish the group's goals. For example, community awareness and incentive to bring slash to a centralized location for chipping, as is done in Gilpin County.

Scope of the Task Force:

The scope of the Peak to Peak Bioenergy Task Force is to find innovative ways in using small diameter wood biomass in the area of Winiger Ridge in order to help reduce the current fire hazard fuel load and to better the community through the use rather than disposal of this otherwise "waste" material.

3. Challenges and Barriers:

The proposal of any project undertaken will require some degree of financial assistance, technical expertise, administrative planning, and community acceptance.

Reality costs were discussed as a group. These costs would encompass transporting material to either a central location, or to a wood heating unit; the cost and time needed to perform a resource assessment to calculate how much biomass will be available in the area; funding a co-gen unit; congressional lobbying; public opinion; establishing a pilot area such as Winiger Ridge; education outreach to the communities effected. This is just an initial list, as there are probably many more reality costs to consider. Each project proposed will bring to the table it's own set of reality costs.

Dan Len suggested that we come up with a general process to follow for each proposed project. For example, a recipe of steps to follow which would include all the important elements such as funding (and where is it coming from), supply (what form is it in and where is it located), transportation (of material), and technology (what type of energy unit and the specifications).

Linda Smith, Tim Rooney, and Matt Ringer each discussed different sources of possible funding depending on the nature of the project. Linda Smith suggested that the Governor's Office for Energy Management and Conservation may be able to offer funding for the "right" project. Tim Rooney mentioned that he has a link to a website that lists funding sources for these types of projects, and Matt Ringer stated that the USDA may contribute funds for feedstock work and that he has ties to the Oak Ridge Lab that he may be able to look into.

Technical support and expertise questions may be directed to Tim Rooney who has been researching bioenergy technology, and also Kurt Mackes who has several research associates working with him who have technical expertise in this area.

Administrative tasks and proposals should be handled by the person(s) who is ultimately in charge of each project initiative. For example, if Mayor Bruntjen would like to head up the effort to see a wood heating unit be placed in the Nederland Community Center/School, then he shall be the principal to submit the proposal for funding and the work to be done.

<u>4. Tasks and Timelines</u>:

Elaine and Tim will continue their efforts in completing a sound resource assessment in the area. The aid of the task force will be appreciated especially in the private sector.

Elaine will be researching and compiling a list of prospective wood heating units, their specifications, and their costs in the effort to have sound information to place in a proposal. She will be asking Tim Rooney for assistance in this area. Any member that has information about current technology is welcome to bring this information to the table for the next meeting.

Any member that has sound funding information that they can bring to the table for the next meeting would be appreciated.

A business plan or course of action, as Dan Len suggested, will need to be established and followed. A proposal outline to use as a standard form should be created, although different funding sources may require special/unique formats.

Mayor Bruntjen may want to look into the specific type of heating that the Nederland Community Center/School will need so that the group can focus its efforts more clearly.

<u>5. Where do we go from here?:</u>

The next meeting will be held on Wednesday, December 11, 2002 from 10:00am to 12:00pm, location TBA.

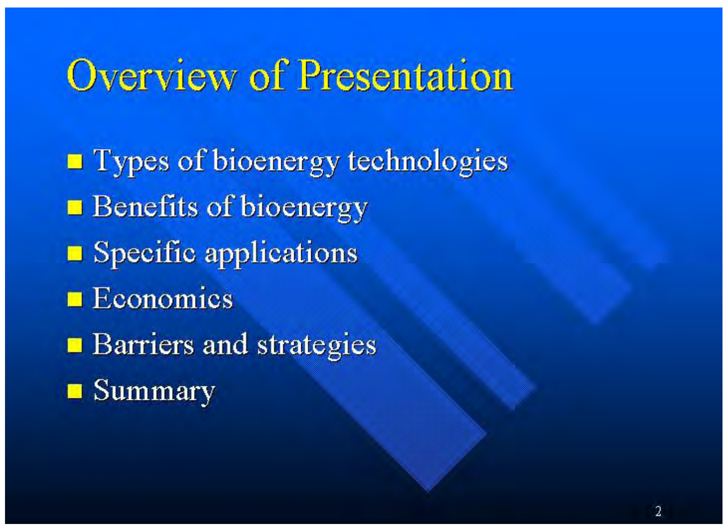
We should bring to the table the items discussed under "Tasks and Timelines" and a report of the status. Also, any new business/ideas may be discussed.

As a group we should be moving forward out of the "Thinking and Brainstorming" stage and into the "Planning and Implementation" stages.

Presentation by Scott Haase, McNeil Technologies, August 30, 2002

S.Haase Slide 1

S.Haase Slide 2



S.Haase Slide 3

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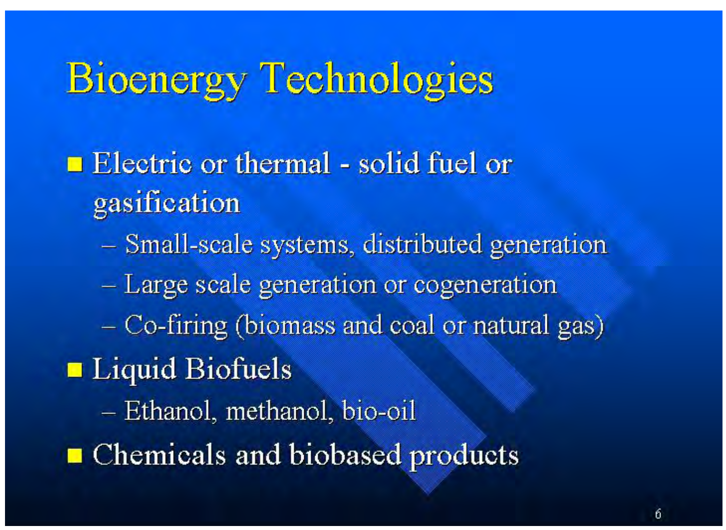
Slide 6</td><td>
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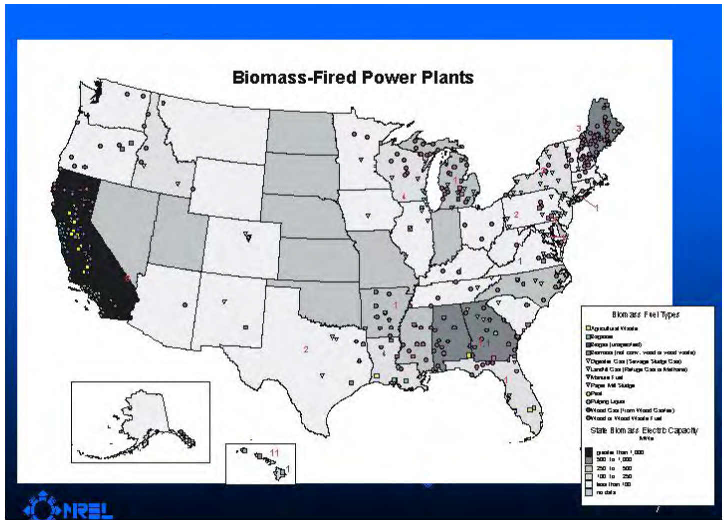

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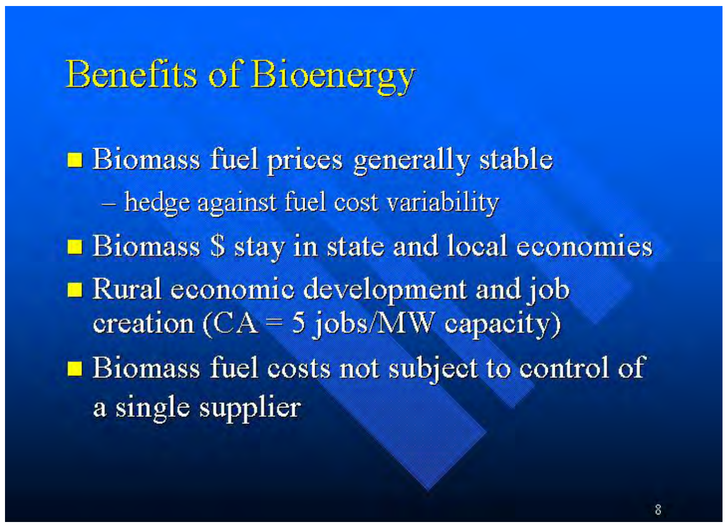

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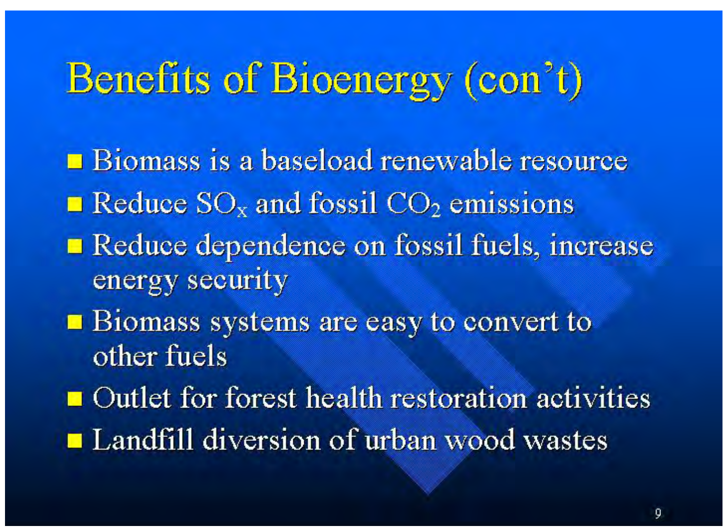

S.Haase Slide 10	**Applications for Bioenergy** ■ Small-scale power or cogeneration systems ■ Merchant biomass generating plants – Utility grid support in strategic locations – Stand-alone biomass plants (~20 MW min) ■ Wood heating at small facilities – Ski areas, schools, hospitals ■ Co-fire in industrial or utility boilers – Holcim cement, Cañon City power plant ■ Liquid fuels, specialty chemicals 10
S.Haase Slide 11	**Emissions** ■ Modern biomass technologies are automated, efficient and clean burning ■ Emissions from plants can be controlled through scrubbers, precipitators, baghouse ■ Biomass has almost no sulfur ■ What are the emissions of biomass plants vs. prescribed burning, wildfires or slash burning? 11
S.Haase Slide 12	**Emissions Associated with Forest Management** ■ Prescribed burning – 60 lbs PM_{10}/ton of fuel – .15 tons PM_{10}/acre burned » (assumes 10 tons per acre fuel loading and 50 percent of that is burned) – In 2001, 28,000 acres prescribe burned in CO, or ~ 4,200 tons PM_{10} ■ Combustion biomass plant – Burning same amount of fuel from 28,000 acres prescribed burn would yield ~ 50 tons PM_{10} 12

S.Haase Slide 13	
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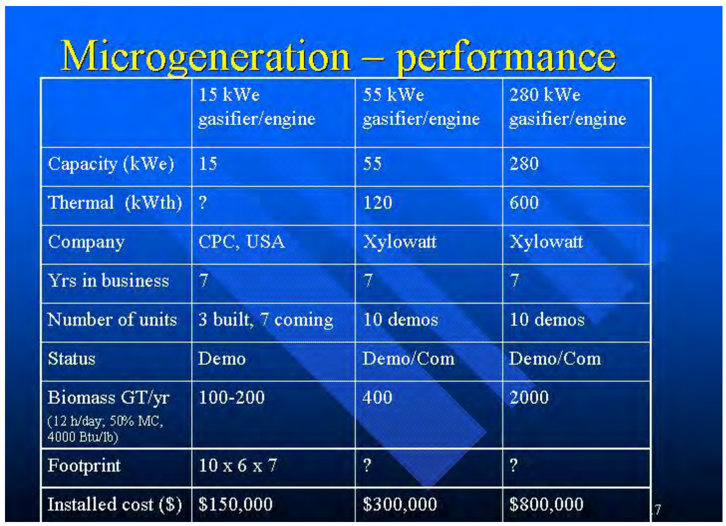

Microgeneration – performance

	15 kWe gasifier/engine	55 kWe gasifier/engine	280 kWe gasifier/engine
Capacity (kWe)	15	55	280
Thermal (kWth)	?	120	600
Company	CPC, USA	Xylowatt	Xylowatt
Yrs in business	7	7	7
Number of units	3 built, 7 coming	10 demos	10 demos
Status	Demo	Demo/Com	Demo/Com
Biomass GT/yr (12 h/day, 50% MC, 4000 Btu/lb)	100-200	400	2000
Footprint	10 x 6 x 7	?	?
Installed cost ($)	$150,000	$300,000	$800,000

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S.Haase
Slide 18

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Chiptec Systems, Vermont

- Heat only or CHP
- 5 – 45% MC
- Wide range of sizes
- Turnkey systems
- Co-gen (35 kW – 5 MW)
- Automated fuel handling

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S.Haase
Slide 20

Other Wood Heating System Manufacturers

- Messersmith Manufacturers (Michigan)
- Grove Wood Heating, Inc (Canada)
- Industrial Boiler Company (Georgia)
- KMW Energy Systems, Inc (Canada)

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Slide 21

Facility heating system performance

	Wood furnace	Wood gasifier/burner	Wood gasifier/burner
Thermal capacity	0.03 – 1 MWth (115k – 1 MMBtu/hr)	0.1 - 3 MWth (.5 – 14 MMBtu/hr)	0.6 – 12 MWth (2 – 40 MMBtu/hr)
Company	Taylor Waterstoves	Chiptec	Converta Kiln
Installed cost	$4,500 - $65,000	$30,000 – $275,000 (gasifier only)	??
Status	Commercial	Commercial	Commercial
Years in business	Not Known	16	Not known
Biomass use (GT/year)	150 – 3,000	330 – 10,000	2,000 – 40,000
# systems in operation	1000s	>125 in NA	300-400

Note: Biomass use estimates assume 0.90 capacity, 33,475 Btu-h/boiler hp, and 4,000 Btu/wet lb biomass heat content

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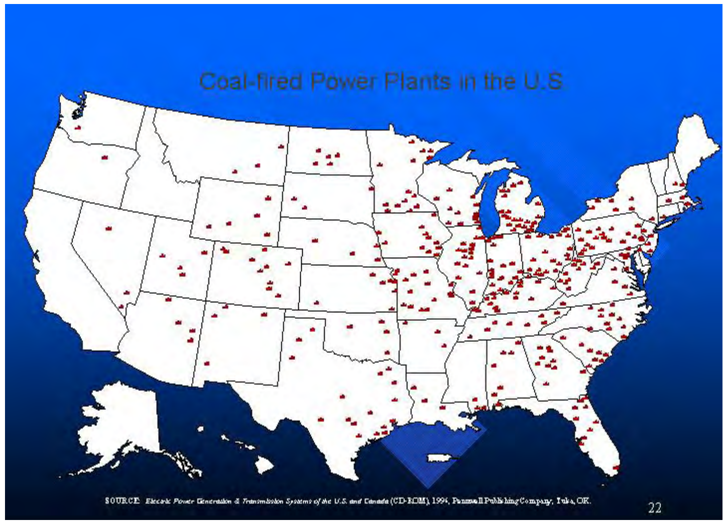
Slide 22



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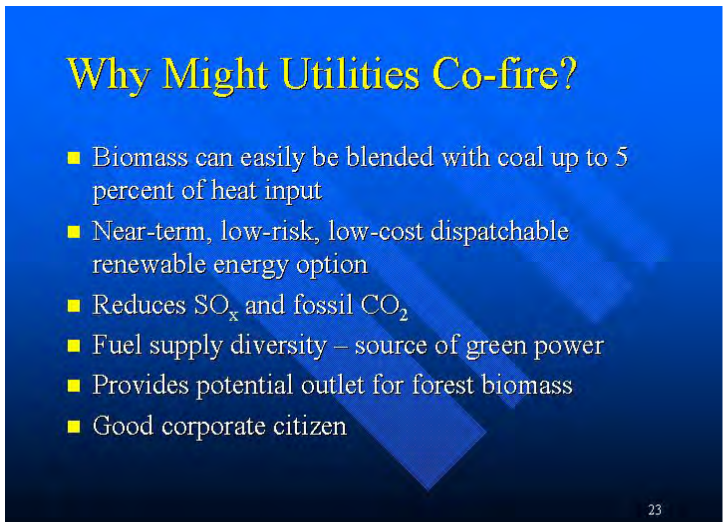

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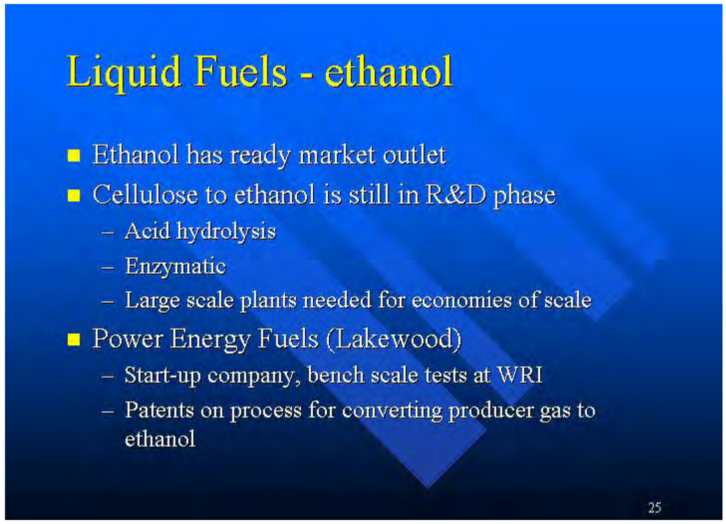
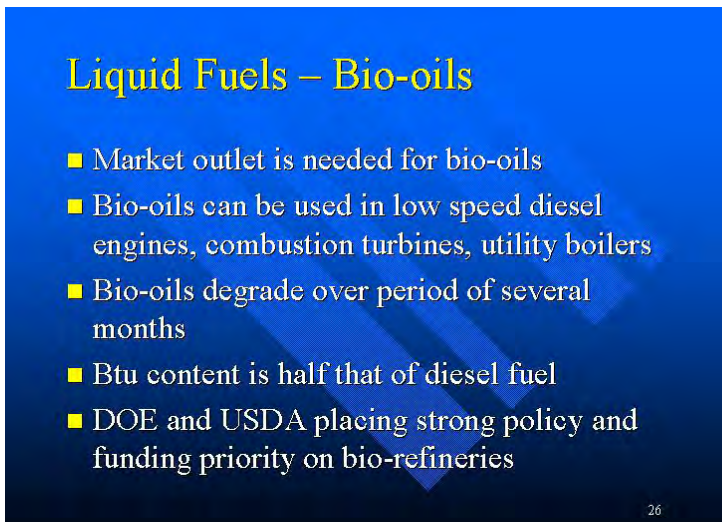


Liquid Fuels - ethanol

- Ethanol has ready market outlet
- Cellulose to ethanol is still in R&D phase
  - Acid hydrolysis
  - Enzymatic
  - Large scale plants needed for economies of scale
- Power Energy Fuels (Lakewood)
  - Start-up company, bench scale tests at WRI
  - Patents on process for converting producer gas to ethanol

25

S.Haase
Slide 26



Liquid Fuels – Bio-oils

- Market outlet is needed for bio-oils
- Bio-oils can be used in low speed diesel engines, combustion turbines, utility boilers
- Bio-oils degrade over period of several months
- Btu content is half that of diesel fuel
- DOE and USDA placing strong policy and funding priority on bio-refineries

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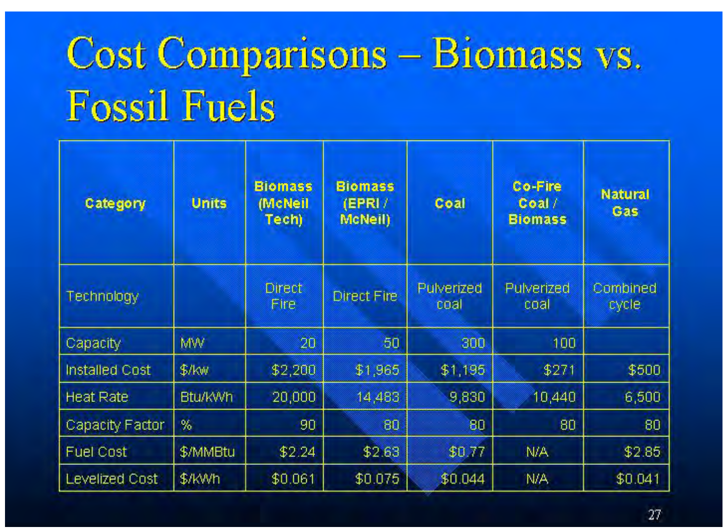
S.Haase
Slide 27



Cost Comparisons – Biomass vs. Fossil Fuels

Category	Units	Biomass (McNeil Tech)	Biomass (EPRI / McNeil)	Coal	Co-Fire Coal / Biomass	Natural Gas
Technology		Direct Fire	Direct Fire	Pulverized coal	Pulverized coal	Combined cycle
Capacity	MW	20	50	300	100	
Installed Cost	$/kw	$2,200	$1,965	$1,195	$271	$500
Heat Rate	Btu/kWh	20,000	14,483	9,830	10,440	6,500
Capacity Factor	%	90	80	80	80	80
Fuel Cost	$/MMBtu	$2.24	$2.63	$0.77	N/A	$2.85
Levelized Cost	$/kWh	$0.061	$0.075	$0.044	N/A	$0.041

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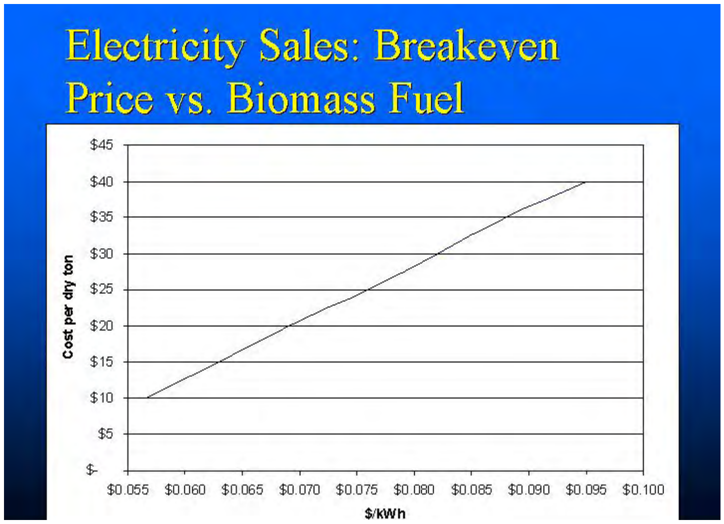
S.Haase Slide 28



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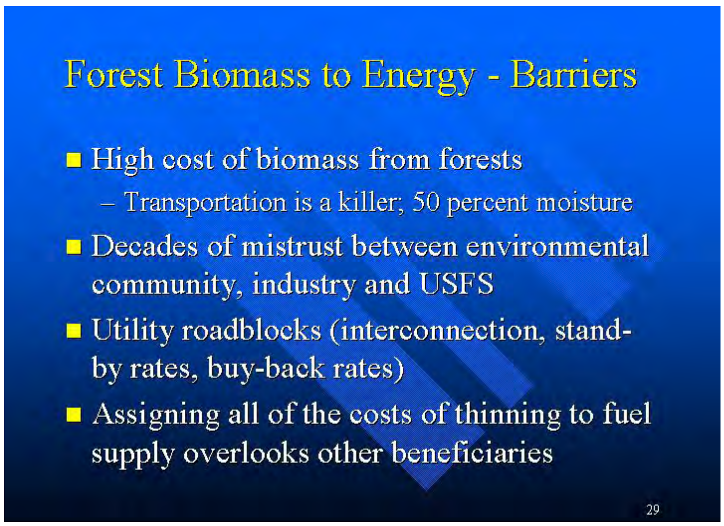

S.Haase Slide 30

S.Haase Slide 31	**How to Pay for Forest Restoration?** ■ Current market outlets for small diameter trees not able to cover costs of removal ■ Taxes – stewardship contracts – biomass to energy tax credit – production tax credit ■ Biomass power – rate base vs. green pricing ■ Watershed protection fee through water utilities – ten cents/1,000 gallons 31
S.Haase Slide 32	**Options for Nederland** ■ Pursue small-scale demonstration project (either heating/cooling or cogeneration) ■ Size system conservatively to meet resource base and facility loads ■ Pursue cost-shared funding to reduce risk 32
S.Haase Slide 33	**Potential Next Steps – Phase I** ■ Obtain funding (for Phase I only or both?) ■ Conduct biomass resource assessment » How many tons, where located, how long? ■ Identify potential host facilities ■ Meet with facility energy managers ■ Evaluate electrical and thermal loads ■ Identify candidate systems – match to load ■ Economic analysis 33

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Slide 34

S.Haase
Slide 35

S.Haase
Slide 36

Workshop invitees and Task Force members

Nederland Bioenergy Meeting Invitee List

Person	Organization
• Raul Bustamante	United Wood Products
• Scott Bruntjen	Nederland Committee on Forest Management
• Bill Carpenter	Landowner
• Hillary Collins	Boulder County Slash Program
• Craig Cox	Colorado Coalition for New Energy Technologies
• Bob Dettmann	U.S. Forest Service
• Chief Rick Dirr	NFPD (Nederland Fire Protection District)
• Eric Douglas	Gilpin County
• Joe Duda	Colorado State Forest Service
• Scott Haase	McNeil Technologies, Inc.
• Dave Hessel	Colorado State Forest Service
• Amy Krommes	U.S. Forest Service, Boulder Ranger District
• Craig Jones	Colorado State Forest Service
• Dr. Merrill Kaufmann	U.S. Forest Service
• Daniel Len	U.S. Forest Service
• Ed Lewis	Governor's Office of Energy Management and Conservation
• Dr. Kurt Mackes	Colorado State University
• Mark Martin	U.S. Forest Service
• Craig Nicholson	Gilpin County Commissioner
• John Nielsen	Land and Water Fund of Rockies
• Allen Owen	Colorado State Forest Service
• Laurelyn Parcell	Nederland Committee on Forest Management
• Eric Phillips	Boulder County Wildfire Mitigation
• Tom Plant	Colorado State Legislature
• Tim Rooney	McNeil Technologies, Inc.
• Gary Sanfacon	Peak to Peak Healthy Communities Project
• Linda Smith	Governor's Office of Energy Management and Conservation
• Rocky Smith	Colorado Wild
• The Honorable Mark Udall	Member, House of Representatives, U.S. Congress
• Christine Walsh	U.S. Forest Service, Boulder Ranger District
• Robb Walt	Community Power Corporation
• Morely Wolfson	National Renewable Energy Lab
• Rocky Wylie	Denver Water Board
• Doug Young	Mark Udall's Office
• Ron Stewart	Boulder County Commissioners
• Randy Coombs	Boulder County Parks and Open Space
• Scott Reuman	PUMA
• TBD	Clear Creek County Commissioners
• TBD	Nederland Town Board
• TBD	City of Boulder

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Appendix B. Utility Customer Survey

The figure below shows the survey questions and format. The survey contained 7 questions, and was focused on determining public knowledge of wildfire threat and biomass, and their interest in buying electricity that is generated using biomass from forest thinnings.

4830430798

Phone Number (_ _ _) _ _ _ - _ _ _ _ **County** **ZIP Code**

Are you aware of the wildfire threat facing Colorado's forests?

○ Yes
○ No

Do you live in an area where you and your property could be directly threatened by a large forest fire?

○ Yes
○ No
○ Don't know

One way to reduce the threat of wildfires is to thin forests by removing small trees and brush that fuel wildfires.

Have you heard of forest thinning?

○ Yes
○ No

Wood removed from forest thinning can be used to create electricity.
Would you be willing to buy electricity from your utility that is generated from wood removed from the forests?

○ Yes
○ No
○ Don't know

Which of these potential benefits of using wood removed from Colorado forests do you feel would be most important?

○ Improving forest health
○ Reducing the risk of wildfires
○ Reducing Colorado's dependence on fossil fuels
○ Reducing the risk of global warming
○ Don't know

Electricity generated from wood removed from the forests is more expensive than regular electricity. **Would you be willing to pay more for electricity produced from forest thinnings if it could be generated in a way that protects the environment?**

○ Yes
○ No
○ Don't know

If yes, how much extra would you be willing to pay on a monthly basis?

○ $5.00
○ $10.00
○ $15.00
○ Other________________

Appendix C. Non-hydro Power Plants in the Study Area

Plant name	Latitude	Longitude	Operator	Power Control Area Name	County	Primary fuel	Nameplate capacity (MW)
Arapahoe	39.67000	-105.00280	Xcel Energy	PSCo/PCA	Denver	Coal	232
Cherokee	39.86970	-104.37900	Xcel Energy	PSCo/PCA	Denver	Coal	717
Comanche	38.20810	-104.57470	Xcel Energy	PSCo/PCA	Pueblo	Coal	700
George Birdsall	38.83000	-104.52000	City of Colorado Springs	WAPA - Rocky Mountains/PCA	El Paso	Natural gas	58
Martin Drake	38.82440	-104.83310	City of Colorado Springs	WAPA - Rocky Mountains/PCA	El Paso	Coal	294
Pueblo	38.17000	-104.51000	West Plains Energy Co-CO	PSCo/PCA	Pueblo	Natural gas	25
Rawhide	40.85830	-105.02690	Platte River Power Authority	PSCo/PCA	Larimer	Coal	285
Ray D Nixon	38.63060	-104.70560	City of Colorado Springs	WAPA - Rocky Mountains/PCA	El Paso	Coal	301
Trigen Colorado Energy Corp	39.52190	-105.22280	Trigen	PSCo/PCA	Jefferson	Coal	35
University Of Colorado	40.08840	-105.34530	University of Colorado	PSCo/PCA	Boulder	Natural gas	33
Valmont	40.06940	-105.20220	Xcel Energy	PSCo/PCA	Boulder	Coal	211
W N Clark	38.47000	-105.44000	West Plains Energy Co-CO	PSCo/PCA	Fremont	Coal	38
Zuni	39.73750	-105.01810	Xcel Energy	PSCo/PCA	Denver	Natural gas	101

Appendix D. List of Stationary Sources (Excluding Power Generation Facilities, Cement Plants)

Facility Name	Facility Mailing Address	County	SIC	Industry Type	Latitude (Degrees)	Longitude (Degrees)
Acme Foundry Inc	3954 Williams St Denver Co 802053456	Denver	3365	Aluminum Foundries	39.7722	-104.9656
Winner Foundries & Mfg Co	5655 Marshall St Arvada Co 80002	Jefferson	3365	Aluminum Foundries	39.7989	-105.0675
Perma Cast Co	1871 Aspen Cir Pueblo Co 810020000	Pueblo	3365	Aluminum Foundries	38.2492	-104.575
National Printing & Packaging Corp	3800 Quentin St Denver Co 802393440	Denver	2752	Commercial Printing Lithograph	39.7786	-104.9417
Colorado Interstate Gas Co Incinerator	1030 S Royer Colorado Springs Co 80903	El Paso	1311	Crude Petroleum & Natural Gas	38.8194	-104.8147
General Chemical Corp	1271 W Bayaud Ave Denver Co 802231212	Denver	2819	Industrial Inorganic Chemicals	39.7147	-105.0028
Itw Irathane Sys	4045 Sinton Rd Colorado Springs Co 80907	El Paso	3479	Metal Coating And Allied Services,Nec	38.8894	-104.8319
Re Monks Const Co	8355 Vollmer Rd Colorado Springs Co 80936	El Paso	3273	Ready-Mixed Concrete	38.9497	-104.6942
Super Vac Mfg Co Inc	1531 E 11th St Loveland Co 80537	Larimer	3341	Secondary Nonferrous Metals	40.4042	-105.0553
Western Mobile Denver Park 85 Plt	11255 Dumont Wy Littleton Co 80125	Douglas	3272	Concrete Products, Nec	39.5394	-105.0375
Transit Mix Concrete Co	3749 N Nevada Ave Colorado Springs Co 80933	El Paso	3272	Concrete Products, Nec	38.8853	-104.8181
Teilhaber Manufacturing Corporation	2360 Industrial Lane Broomfield Co 80038	Boulder	2542	Metal Partitions And Fixtures	40.1567	-105.5814
Fagan Iron & Metal	4601 Glencoe St Denver Co 802166418	Denver	5093	Scrap And Waste Materials	39.7803	-104.9256
Chemical Handling	11811 Upham St Broomfield Co 80038	Jefferson	1311	Crude Petroleum & Natural Gas	39.9117	-105.0769
Jemm Co	3300 Walnut St Denver Co 802052430	Denver	3471	Electroplating,Polishing,Anodizing, And	39.7658	-104.9772
Cai Technologies	777 Umatilla St Denver Co 802044225	Denver	3559	Special Industry Machinery Nec	39.7292	-105.0117
Power Application & Mfg Co	10777 E 45th Ave Denver Co 802392905	Denver	3563	Air And Gas Compressors	39.7789	-104.8622
Mountain West Printing & Publishing	1150 W Custer Pl Denver Co 802232317	Denver	2752	Commercial Printing Lithograph	39.7067	-105.0011
Colorado Concrete Mfg Co	3155 Drennan Rd Colorado Springs Co 80935	El Paso	3273	Ready-Mixed Concrete	38.7811	-104.7714
Decals Inc	4850 Ward Rd Wheat Ridge Co 80033	Jefferson	2759	Commercial Printing, Nec	39.8719	-105.3744
Colorado Silica Sand Processing Plt	3250 Drennan Rd Colorado Springs Co 80906	El Paso	1442	Construction Sand And Gravel	38.7817	-104.7706
Power Engineering	2525 S Delaware St Denver Co 802234400	Denver	3471	Electroplating,Polishing,Anodizing, And	39.6708	-104.9919
Eastern Elec Apparatus Repair Co	700 W 43rd Ave Denver Co 802162608	Denver	7694	Armature Rewinding Shops	39.7756	-104.9956
Layton Truck Equipment Co	555 Ford St Colorado Springs Co 80915	El Paso	5012	Autos & Other Motor Vehicles	38.84	-104.71
General Electric Co	4900 Kingston St Denver Co 802392526	Denver	7694	Armature Rewinding Shops	39.7894	-104.8586
Peerless Alloy Inc	1445 Osage St Denver Co 802042439	Denver	3341	Secondary Nonferrous Metals	39.7392	-105.005
Huerfano Cnty Medical Ctr	23500 Us Hwy 160 Walsenburg Co 81089	Huerfano	8062	General Medical & Surgical Hospitals	37.6114	-104.8061
Usarmy Hq Ft Carson 4th Inf Mec Pcms	36086 Us Hwy 350 Model Co 810820000	Las Anima	9711	National Security	37.5261	-104.1292
Trinidad City Asphalt Plt	Us Hwy I25 Goddard Exit Trinidad Co 81082	Las Anima	2951	Paving Mixtures And Blocks	37.1931	-104.4897
American Ind Svcs	1835 S Broadway Denver Co 802103103	Denver	7211	Power Laundries, Family & Commercial	39.6828	-104.9872
Valley Block Loveland Facility	Rd 402 & Us Hwy I25 .75 Mi E Loveland Co 80537	Larimer	2411	Logging	40.3781	-104.9736
Atlas Metals & Iron Corp Processing Div	3500 Chestnut Pl Denver Co 802163628	Denver	3341	Secondary Nonferrous Metals	39.7719	-104.9803
Kistler Graphics Inc	4000 Dahlia St Denver Co 802164404	Denver	2752	Commercial Printing Lithograph	39.7728	-104.9311
Mobile Premix Concrete Quivas Plt	1151 Quivas St Denver Co 802043417	Denver	3273	Ready-Mixed Concrete	39.6881	-105.0061
Transit Mix Concrete Co	444 E Costilla St Colorado Springs Co 80903	El Paso	3273	Ready-Mixed Concrete	38.8283	-104.8169
Pikes Peak Library District	5550 N Union Blvd Colorado Springs Co 80918	El Paso	8231	Libraries And Information Centers	38.9111	-104.7739
Pease Ind Inc	5000 Lima St Denver Co 802392626	Denver	3442	Metal Doors, Sash, And Trim	39.7897	-104.8567
Goldberg Brothers Inc	8000 E 40th Ave Denver Co 802071711	Denver	3089	Plastics Products, Nec	39.7714	-104.8897
Scotts Liquid Gold Inc	4880 Havana St Denver Co 802392400	Denver	2842	Polishes And Sanitation Goods	39.7856	-104.8656
Ab Hirschfeld Press Inc	5200 Smith Rd Denver Co 802164553	Denver	2752	Commercial Printing Lithograph	39.7744	-104.9217
Iron & Metals Inc	5555 Franklin St Denver Co 802166215	Denver	3341	Secondary Nonferrous Metals	39.7967	-104.9686
Flanagan Ready Mix Div - Riverview Plant	8420 W Riverview Pkwy Littleton Co 80125	Douglas	3272	Concrete Products, Nec	39.5544	-105.0372

Facility Name	Facility Mailing Address	County	SIC	Industry Type	Latitude (Degrees)	Longitude (Degrees)
Trane Co	101 William White Blvd Pueblo Co 81001	Pueblo	3585	Refrigeration & Heating Equipment	38.2786	-104.5208
Adience Inc	309 S 11th St Canon City Co 81212	Fremont	3255	Clay Refractories	38.4422	-105.2308
Coulson Excavating	Se 14th St Loveland Co 80537	Larimer	2952	Asphalt Felts And Coatings	40.3942	-105.0942
Reliance Elec Co	1020 S Lipan St Denver Co 802232719	Denver	7694	Armature Rewinding Shops	39.6981	-105.0011
Colorado Lien Co Fine Grind Owl Canyon	Us Hwy 287 Livermore Co 80521	Larimer	1422	Crushed And Broken Limestone	40.7894	-105.185
Dps Henry	3005 S Golden Wy Denver Co 802273849	Denver	8211	Elementary And Secondary Schools	39.6597	-105.0572
Longmont Wwtp	501 E 1st Ave Longmont Co 80501	Boulder	4952	Sewerage Systems	40.16	-105.1
Gibson'S Inc	E Hwy 50 Salida Co 81212	Chaffee	5331	Variety Stores	38.52	-106.0392
Mid America Plating Inc	4877 National Western Dr Denver Co 802162126	Denver	3471	Electroplating,Polishing,Anodizing, And	39.7883	-104.9683
Cheyenne Mtn Zoo	4250 Cheyenne Mtn Zoo Rd Colorado Springs Co 80	El Paso	8422	Botanical And Zoological Gardens	38.7778	-104.8556
Whiting Petroleum Corp Kwb 1 Oil Well	Ne Nw Sec 19 T8n R68w Larimer Cnty Co 00000	Larimer	1311	Crude Petroleum & Natural Gas	40.6519	-105.0472
Western Scrap Processing Co_Inc	3315 Drennan Ind Loop S Colorado Springs Co 8093	El Paso	5093	Scrap And Waste Materials	38.7864	-104.7672
Western Foundries	100 Martin St Longmont Co 80501	Boulder	3321	Gray Iron Foundries	40.1611	-105.0922
Us Mix Products Co	112 S Santa Fe Dr Denver Co 802231815	Denver	3272	Concrete Products, Nec	39.7144	-104.9978
Mckinney Concrete	2700 N Freeway Pueblo Co 81003	Pueblo	3273	Ready-Mixed Concrete	38.2953	-104.6086
Persolite Products Inc Persolite Plt	215 S Robinson Ave Florence Co 81226	Fremont	3295	Minerals, Ground Or Treated	38.3914	-105.1103
Pete Lien & Sons Inc	3375 Drennan Industrial Loop Colorado Springs Co 8	El Paso	3271	Concrete Block And Brick	38.7864	-104.7672
Mitchell Senior High Sch	1205 Potter Dr Colorado Springs Co 80909	El Paso	8211	Elementary And Secondary Schools	38.8497	-104.7519
Colorado Springs City Pine Valley Wtp	8450 N Academy Blvd Colorado Springs Co 80840	El Paso	9511	Air, Water & Solid Waste Management	38.9517	-104.8058
Colorado Container Corp	4221 Monaco St Denver Co 802166643	Denver	2752	Commercial Printing Lithograph	39.7744	-104.9128
Current Inc	1005 E Woodmen Rd Colorado Springs Co 80911000	El Paso	2771	Greeting Card Publishing	38.9328	-104.8031
Superior Precision Sheet Metal Micro	4715 N Chestnut Colorado Springs Co 80907	El Paso	3444	Sheet Metal Work	38.8989	-104.8353
Grace Membrane Sys	8101 W Midway Dr Littleton Co 801250000	Douglas	3089	Plastics Products, Nec	39.5483	-105.0367
Allegro Coffee Co	1930 Central Ave Boulder Co 803010000	Boulder	2095	Roasted Coffee	40.0197	-105.2189
Caterpillar Inc	4705 E 48th Ave Denver Co 802163213	Denver	5083	Farm Machinery And Equipment	39.7839	-104.9339
Rosemont Pharmaceutical Corp	301 S Cherokee St Denver Co 802232114	Denver	2834	Pharmaceutical Preparations	39.7108	-104.9919
Dps Gove	4050 E 14th Ave Denver Co 802202308	Denver	8211	Elementary And Secondary Schools	39.7381	-104.9394
Dps East High	1545 Detroit St Denver Co 802061515	Denver	8211	Elementary And Secondary Schools	39.7411	-104.9544
Dps Martin Luther King	19535 46th Ave Denver Co 802496637	Denver	8211	Elementary And Secondary Schools	39.7806	-104.7592
Mile High Equipment Co	11100 E 45th Ave Denver Co 802393029	Denver	3632	Household Refrigerators/Freezers	39.7783	-104.8581
Dps South High	1700 E Louisiana Ave Denver Co 802101810	Denver	8211	Elementary And Secondary Schools	39.6928	-104.9669
Dps Kennedy	2855 S Lamar Dr Denver Co 802273809	Denver	8211	Elementary And Secondary Schools	39.6631	-105.0672
Dps Thomas Jefferson	3950 S Holly St Denver Co 802371117	Denver	8211	Elementary And Secondary Schools	39.6464	-104.9217
Graphics Packaging Corp	3825 Walnut St Boulder Co 80303	Boulder	2641	Paper Coating And Glazing(1977)	40.0197	-105.2456
Colorado Springs Rehab Hosp	325 Parkside Dr Colorado Springs Co 80910	El Paso	8069	Specialty Hospitals, Except Psychiatric	38.8297	-104.7853
Dps Carson	5420 E 1st Ave Denver Co 802205801	Denver	8211	Elementary And Secondary Schools	39.7178	-104.9236
Energy Fuels Coal Inc Southfield Mine	Sec 30 T20s R69t Florence_8 Mi S Of Co 81226	Fremont	1211	Bituminous Coal And Lignite(1977)	38.2864	-105.1519
Dfc Ceramics	515 S Ninth St Canon City Co 81212	Fremont	3255	Clay Refractories	38.4392	-105.2319
Coors Ceramics Company	16000 Table Mountain Pkwy Golden Co 80403	Jefferson	3255	Clay Refractories	39.7833	-105.1775
Protecto Wrap Co	2255 S Delaware St Denver Co 802234190	Denver	2295	Coated Fabrics, Not Rubberized	39.6758	-104.9919
American Web Inc	4040 Dahlia St Denver Co 802164430	Denver	2752	Commercial Printing Lithograph	39.73	-104.98
Colorado Dept Of Corrections	10900 Smith Rd Bldg F Denver Co 802393262	Denver	9223	Correctional Institutions	39.7681	-104.8608
Stone Container Corp	5050 E 50th Ave Denver Co 802163107	Denver	2653	Corrugated And Solid Fiber Box	39.7872	-104.9281
Willamette Ind Inc	4565 Indiana St Golden Co 80403	Jefferson	2653	Corrugated And Solid Fiber Box	39.7789	-105.165

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Inland Paperboard And Packaging Inc	5000 Oak Street Wheat Ridge Co 80033	Jefferson	2653	Corrugated And Solid Fiber Box	39.8719	-105.3744
Public Service Co Williams Fork	Sec 23 T2s R78w Marshall Co 80468	Grand	1311	Crude Petroleum & Natural Gas	39.8628	-106.0897
Doane Products Co	1 Doane Pl Pueblo Co 81006	Pueblo	2047	Dog Cat And Other Pet Food	38.3089	-104.5025
Dps Hill Jr	451 Clermont St Denver Co 802205019	Denver	8211	Elementary And Secondary Schools	39.7236	-104.9342
Dps Opportunity	1250 Welton Denver Co 802042124	Denver	8211	Elementary And Secondary Schools	39.7411	-104.995
Dps North High	2960 N Speer Blvd Denver Co 802113793	Denver	8211	Elementary And Secondary Schools	39.76	-105.0233
Dps Abraham Lincoln	2285 S Federal Blvd Denver Co 802195433	Denver	8211	Elementary And Secondary Schools	39.6767	-105.0244
Safeway Milk Plt	4301 Forest St Denver Co 802164540	Denver	2026	Fluid Milk	39.7769	-104.9269
Robinson Dairy Inc	2401 W 6th Ave Denver Co 802044101	Denver	2026	Fluid Milk	39.73	-104.98
Sinton Dairy Foods Co	3801 N Sinton Rd Colorado Springs Co 80901	El Paso	2026	Fluid Milk	38.8856	-104.8331
Boulder Community Hospital	1100 Balsam Boulder Co 80304	Boulder	8062	General Medical & Surgical Hospitals	40.0267	-105.2822
Colorado Mental Health Ctr	4075 S Lowell Blvd Denver Co 802363120	Denver	8062	General Medical & Surgical Hospitals	39.6428	-105.0344
St Vincents Hosp	West 4th & Washington Leadville Co 80461	Lake	8062	General Medical & Surgical Hospitals	39.245	-106.3003
Cripple Creek & Victor Gold Mining Co	2755 Hwy 67 & 2917 Cnty Rd 84 Victor Co 80860	Teller	1041	Gold Ores	38.7333	-105.1611
Schlage Lock Co	3899 Hancock Expy Security Co 809110000	El Paso	3429	Hardware, Nec	38.7725	-104.7386
Parkview Episcopal Medical Ctr	400 W 16th St Pueblo Co 81003	Pueblo	6324	Hospital And Medical Service P	38.2814	-104.6114
The Alta Group Inc	6945 Indiana Ct_No 200 Arvada Co 800070000	Jefferson	2819	Industrial Inorganic Chemicals	39.8222	-105.1658
Chronopol Inc	4545 Mcintyre St Golden Co 80403	Jefferson	2819	Industrial Inorganic Chemicals	39.7806	-105.1753
G&K Services Inc	5100 Race Ct Denver Co 802162135	Denver	7218	Industrial Launderers	39.7886	-104.965
Colorado Lein Co La Porte	N Overland Trl La Porte Co 80535	Larimer	1446	Industrial Sand	40.6119	-105.1692
Natl Linen Svc No 27	3850 Elm St Denver Co 802071030	Denver	7213	Linen Supply	39.7706	-104.9289
Central Uniform	802 S Wahsatch Colorado Springs Co 80903	El Paso	7213	Linen Supply	38.8217	-104.8183
Sno White Linen & Uniform Rental Inc	110 S 25th St Colorado Springs Co 80904	El Paso	7213	Linen Supply	38.8467	-104.8625
Camas Colorado Inc Aspahalt Division	3400 Fox Street Denver Co 802165117	Denver	2951	Paving Mixtures And Blocks	39.7583	-104.9919
Hauser Inc	5555 Airport Blvd Boulder Co 80301	Boulder	2834	Pharmaceutical Preparations	40.0417	-105.2311
Tuscarora Inc	1100 Garden Of The Gods Rd Colorado Springs Co 8	El Paso	3086	Plastics Foam Products	38.8967	-104.8408
Coors Ceramics Mcintyre St	4545 Mcintyre St Golden Co 80403	Jefferson	3264	Porcelain Electrical Supplies	39.7694	-105.1742
Angelica Corp Formerly City Elite	2701 Lawrence St Denver Co 802052226	Denver	7211	Power Laundries, Family & Commercial	39.7592	-104.9828
Cozinco Inc	100 W Zinc St Salida Co 81201	Chaffee	3332	Primary Lead(1977)	38.5328	-105.9947
Climax Molybdenum Amax Henderson Mill	19302 Rd 3 Parshall Co 80468	Grand	3339	Primary Nonferrous Metals, Nec	40	-106.1742
Poudre Pre Mix Inc Plt 2	3000 E Drake Fort Collins Co 80524	Larimer	3273	Ready-Mixed Concrete	40.5525	-105.0219
Sundstrand Fluid Handling Div Of Milton	14845 W 64th Ave Arvada Co 80004	Jefferson	4613	Refined Petroleum Pipe Lines	39.8122	-105.1628
Gold Star Sausage Co	2800 Walnut St Denver Co 802052236	Denver	2013	Sausages & Other Prepared Meat	39.7611	-104.9831
Wood Recovery Sys Inc	3031 Hwy 119 Longmont Co 80501	Boulder	2421	Sawmills & Planing Mills General	40.16	-105.0686
Chriscott Supply Inc	408 Grand County Rd 60 Granby Co 80446	Grand	2421	Sawmills & Planing Mills General	40.0833	-105.9267
Kurt Manufacturing Impact Bus Unit	32500 Perfect Circle Pueblo Co 81001	Pueblo	3341	Secondary Nonferrous Metals	38.2817	-104.4978
Cucina Cucina Inc	1801 Wynkoop St Denver Co 802021098	Denver	3589	Service Industry Machinery Nec	39.73	-104.98
City Of Pueblo Dprt Of Wastewater	1300 S Queen St Pueblo Co 81001	Pueblo	4952	Sewerage Systems	38.17	-104.51
Cu Boulder Svcs Bldg	3200 Marine St Boulder Co 80309	Boulder	4961	Steam Supply	40.0136	-105.2506
Cu Boulder Williams Village	500 30th St Boulder Co 80302	Boulder	4961	Steam Supply	39.9975	-105.2522
Federal Correctional Inst Englewood	9595 W Quincy Ave Littleton Co 80123	Jefferson	4961	Steam Supply	39.6392	-105.1044
Fort Collins City Wastewater Div	3036 E Drake Rd Fort Collins Co 805250000	Larimer	4941	Water Supply	40.5525	-105.0214
Keebler Co	5000 Osage St Denver Co 802211550	Denver	2052	Cookies And Crackers	39.7872	-105.0047
Buena Vista Correctional Facility	15125 Us Hwy 24 & 285 Buena Vista Co 81211	Chaffee	9223	Correctional Institutions	38.8211	-106.1172

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Florence Federal Correctional Instit	5880 State Hwy 67 So Fremont Co 80000	Fremont	9223	Correctional Institutions	38.3639	-105.0983
Colo Territorial Correctional Facility	Downtown Canon City_"Old Max" Canon City Co 812	Fremont	9223	Correctional Institutions	38.4378	-105.2497
Fremont Correctional Facility	Hwy 50 East And Evans Blvd Canon City Co 8121500	Fremont	9223	Correctional Institutions	38.4378	-105.2497
Amoco Production Co	Sec 36 T32s R67w Las Animas Co 80000	Las Animas	1311	Crude Petroleum & Natural Gas	37.2119	-104.8333
Presbyterian Hospital-Denver	1719 E 19th Ave Denver Co 802181281	Denver	8062	General Medical & Surgical Hospitals	39.7472	-104.9661
Denver General Hosp	777 Bannock St Denver Co 802044507	Denver	8062	General Medical & Surgical Hospitals	39.7283	-104.99
Provenant Healthcare Partners	4231 W 16th Ave Denver Co 802041374	Denver	8062	General Medical & Surgical Hospitals	39.7428	-105.0425
St Francis Penrose Hosp Sys	825 E Pikes Peak Colorado Springs Co 809030000	El Paso	8062	General Medical & Surgical Hospitals	38.8333	-104.8092
St Mary Corwin Medical Center	1008 Minnequa Ave Pueblo Co 81004	Pueblo	8062	General Medical & Surgical Hospitals	38.2331	-104.6217
Pepcol Mfg Co	4647 National Western Dr Denver Co 802162122	Denver	2011	Meat Packing Plants	39.7808	-104.9756
Ball Metal Beverage Container Corp	4525 Indiana St Golden Co 80401	Jefferson	3411	Metal Cans	39.7783	-105.165
Kbp Coil Coaters Inc	3600 E 44th Ave Denver Co 802166527	Denver	3479	Metal Coating And Allied Services,Nec	39.7781	-104.9453
Falcon Afb Usaf	500 Navstar Falcon Afb Co 809125000	El Paso	9711	National Security	38.8592	-104.5967
Schmidt Const Co	1101 Topeka Wy Castle Rock Co 801040000	Douglas	2951	Paving Mixtures And Blocks	39.3708	-104.8697
Tony J Beltramo & Sons Inc	1541 Stockyard Rd Pueblo Co 81001	Pueblo	2951	Paving Mixtures And Blocks	38.2564	-104.5825
Brannan Sand & Gravel	4090 Galapago St Denver Co 802164843	Denver	3273	Ready-Mixed Concrete	39.7842	-104.9661
Bfi Boulder Marshall Ldfl	1600 S 66th St Boulder Co 80306	Boulder	4953	Refuse Systems	39.9611	-105.1997
Us Postal Svc	1501 Wynkoop St Denver Co 802663001	Denver	4311	U.S. Postal Service	39.7519	-105.0058
Colorado College Williams Heating Plt	908 N Cascade Colorado Springs Co 80903	El Paso	8221	Colleges And Universities, Nec	38.8467	-104.8242
University Of Southern Co	2200 W Bonforte Blvd Pueblo Co 81001	Pueblo	8221	Colleges And Universities, Nec	38.3047	-104.5797
Lutheran Medical Ctr	8300 W 38th Ave Wheat Ridge Co 80033	Jefferson	3822	Environmental Controls	39.7689	-105.0892
Climax Molybdenum Amax Climax Mine Mill	Hwy 91 At Fremont Pass Climax Co 80429	Lake	1061	Ferroalloy Ores Exc Vanadium	39.3675	-106.1842
General Svcs Administration	6th Ave & Kipling St Denver Co 80225	Jefferson	9199	General Government, Nec	39.7233	-105.1092
Rose Medical Ctr	4567 E 9th Ave Denver Co 802203941	Denver	8062	General Medical & Surgical Hospitals	39.7311	-104.9339
Penrose Community Hospital	3205 N Academy Blvd Colo Springs Co 80917	El Paso	8062	General Medical & Surgical Hospitals	38.83	-104.52
Poudre Valley Hosp	1024 S Lemay Ave Fort Collins Co 805220000	Larimer	8062	General Medical & Surgical Hospitals	40.5753	-105.0572
Samsonite Corp	11200 E 45th Ave Denver Co 802393000	Denver	3079	Miscellaneous Plastics Products(1977)	39.7783	-104.8575
Pueblo Chemical Depot Usarmy	14 Mi E Of Pueblo On Hwy 50 Pueblo Co 810015000	Pueblo	9711	National Security	38.2925	-104.3219
Syntex Chemical Inc	2075 N 55th St Boulder Co 80301	Boulder	2834	Pharmaceutical Preparations	40.0203	-105.225
Manna Pro Partners Lp	4545 Madison St Denver Co 802164235	Denver	2048	Prepared Feeds Nec	39.7797	-104.9464
Cis Oil & Gas	Sec 28 T34s R64w Las Animas Co 00000	Las Animas	1311	Crude Petroleum & Natural Gas	37.6811	-104.1958
Longmont Foods	150 Main St Longmont Co 805021479	Boulder	2099	Food Preparations Nec	40.1617	-105.1014
St Joseph Hosp	1835 Franklin St Denver Co 802181191	Denver	8062	General Medical & Surgical Hospitals	39.7453	-104.9683
Memorial Hospital	1400 E Boulder St Colorado Springs Co 80909	El Paso	8062	General Medical & Surgical Hospitals	38.8389	-104.7994
Geneva Pharmaceuticals Inc	2555 W Midway Blvd Broomfield Co 800200000	Boulder	2834	Pharmaceutical Preparations	39.9242	-105.1028
Childrens Hosp	1056 E 19th Ave Denver Co 802181088	Denver	8069	Specialty Hospitals, Except Psychiatric	39.7461	-104.9739
Florence Federal Correctional Institutn	5880 Hwy 67 S Florence Co 81226	Fremont	2521	Wood Office Furniture	38.3781	-105.1111
Presbyterian St Lukes	1719 E 19th St Denver Co 802021005	Denver	8069	Specialty Hospitals, Except Psychiatric	39.755	-104.9969
El Paso Cnty	301 S Union Blvd Colorado Springs Co 80910	El Paso	9532	Urban And Community Development	38.8261	-104.7942
Pepsi Cola Bottling Co	3801 Brighton Blvd Denver Co 802163693	Denver	2086	Bottled And Canned Soft Drinks	39.7733	-104.9753
Custer County Road & Bridge	Rd 328 Westcliffe 6 Mi Se Of Co 00000	Custer	1442	Construction Sand And Gravel	38.0833	-105.4167
Chimill Corp	4300 Oneida St Denver Co 802166616	Denver	2096	Potato Chips And Similar Snacks	39.7769	-104.9078
Waste Management Disposal Service Of Csp	13320 E Hwy 94 Colorado Springs Co 80920	El Paso	4953	Refuse Systems	38.8386	-104.5731
Public Service Co Deer Creek Station	Sec 4 T6s R69w Golden Co 80419	Jefferson	1311	Crude Petroleum & Natural Gas	39.5553	-105.12

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Cheyenne Mountain Air Station	1 Norad Rd Colorado Springs Co 809146098	El Paso	9711	National Security	38.7456	-104.8467
Frito Lay Inc	11645 E 37th Ave Denver Co 802393304	Denver	2099	Food Preparations Nec	39.7686	-104.8528
Longmont United Hosp	1950 W Mountain View Ave Longmont Co 80501	Boulder	8062	General Medical & Surgical Hospitals	40.1817	-105.1242
Mckee Medical Ctr	2000 Boise Ave Loveland Co 805380000	Larimer	8062	General Medical & Surgical Hospitals	40.4114	-105.0531
G-P Gypsum Corp	1173 Hwy 120 Florence Co 81226	Fremont	3275	Gypsum Products	38.3947	-105.0319
Denver Brick Co	401 Santa Fe Rd Castle Rock Co 80104	Douglas	3251	Brick And Structural Clay Tile	39.3761	-104.8664
Johns Manville International	10100 W Ute Ave Littleton Co 80127	Jefferson	8731	Commercial Physical Research	39.5578	-105.1067
Public Service Co Leyden Station	Sec 25 T2s R70w Golden Co 80419	Jefferson	1311	Crude Petroleum & Natural Gas	39.845	-105.1747
Amoco Production Co Garcia Swift No 1	Sec 29 T32s R66w Las Animas Co 80000	Las Anima	1311	Crude Petroleum & Natural Gas	37.6811	-104.1958
Amoco Production Co Piaskoski No 1	Sec 29 T32s R66w Las Animas Co 80000	Las Anima	1311	Crude Petroleum & Natural Gas	37.6811	-104.1958
Amoco Production Co Dixon No 1	Sec 25 T32s R67w Las Animas Co 80000	Las Anima	1311	Crude Petroleum & Natural Gas	37.6811	-104.1958
Amoco Production Co Givens No 1	Sec 25 T32s R67w Las Animas Co 80000	Las Anima	1311	Crude Petroleum & Natural Gas	37.6811	-104.1958
Amoco Production Co	Sec 36 T32s R67w Las Animas Co 80000	Las Anima	1311	Crude Petroleum & Natural Gas	37.6811	-104.1958
Pikes Peak Community College	5675 S Academy Blvd Colorado Springs Co 80911	El Paso	8222	Junior Colleges	38.7656	-104.7836
Public Service Co Front Range	Sec 12 T4s R70w Golden Co 80419	Jefferson	1311	Crude Petroleum & Natural Gas	39.7189	-105.1731
Amoco Usa Operations Burrow Can No1	Sw Sec 28 T32s R66w Las Animas Cnty Co 00000	Las Anima	1311	Crude Petroleum & Natural Gas	37.6811	-104.1958
Amoco Usa Operations State At No2	Nw Sec 16 T32s R66w Las Animas Cnty Co 00000	Las Anima	1311	Crude Petroleum & Natural Gas	37.6811	-104.1958
Amoco Usa Operations Upper Burrow No1	Nw Sec 21 T32s R66w Las Animas Cnty Co 00000	Las Anima	1311	Crude Petroleum & Natural Gas	37.6811	-104.1958
Amoco Usa Operations Wharton No1	Se Sec 32 T32s R66w Las Animas Cnty Co 00000	Las Anima	1311	Crude Petroleum & Natural Gas	37.6811	-104.1958
Amoco Usa Operations Tokar No1	Nw Sec 31 T32s R66w Las Animas Cnty Co 00000	Las Anima	1311	Crude Petroleum & Natural Gas	37.6811	-104.1958
Amoco Usa Operations State At No1	Se Sec 16 T32s R66w Las Animas Cnty Co 00000	Las Anima	1311	Crude Petroleum & Natural Gas	37.6811	-104.1958
Amoco Usa Operations Horn Springs No6	Sw Sec 33 T32s R66w Las Animas Cnty Co 00000	Las Anima	1311	Crude Petroleum & Natural Gas	37.6811	-104.1958
Amoco Usa Operations Lincoln Canyon No1	Ne Sec 21 T32s R66w Las Animas Cnty Co 00000	Las Anima	1311	Crude Petroleum & Natural Gas	37.6811	-104.1958
Amoco Usa Operations Pachorek No2	Sw Sec 31 T32s R66w Las Animas Cnty Co 00000	Las Anima	1311	Crude Petroleum & Natural Gas	37.6811	-104.1958
Amoco Usa Operations Burrow Can No2	Ne Sec 28 T32s R66w Las Animas Cnty Co 00000	Las Anima	1311	Crude Petroleum & Natural Gas	37.6811	-104.1958
Amoco Production Co	Sw Se Sec28 T32s R66w Trinidad Co 81082	Las Anima	1311	Crude Petroleum & Natural Gas	37.2461	-104.7744
Amoco Production Co	Sec 33 T32s R66w Las Animas Co 81054	Las Anima	1311	Crude Petroleum & Natural Gas	37.2183	-104.7858
City Of Boulder 75th St Wwtp	4049 75th St Boulder Co 80301	Boulder	4931	Elec & Other Services Combined	40.0497	-105.1781
Total Petroleum Inc No 2332	495 S Colorado Blvd Denver Co 802468002	Denver	5541	Gasoline Service Stations	39.7092	-104.9403
Penrose Hosp Sisters Of Charity	2215 N Cascade Ave Colorado Springs Co 80933000	El Paso	8062	General Medical & Surgical Hospitals	38.8647	-104.8228
Western Mobile Southern Inc	615 Sante Fe Dr Pueblo Co 81006	Pueblo	2951	Paving Mixtures And Blocks	38.2486	-104.5972
Amgen Boulder Inc	5550 Airport Blvd Boulder Co 80301	Boulder	2834	Pharmaceutical Preparations	40.0417	-105.2311
Us Air Force Acad Dept Of Air Force	8120 Edgertib Dr Ste 40 Air Force Academy Co 8084	El Paso	8221	Colleges And Universities, Nec	39.0003	-104.8822
Cooley Gravel Co	18131 Colo Hwy 8 Morrison Co 80465	Jefferson	1442	Construction Sand And Gravel	39.6361	-105.1928
Amoco Production Co	Ne Sec 33 T32s R66w Las Animas Cnty Co 00000	Las Anima	1311	Crude Petroleum & Natural Gas	37.2192	-104.7858
Southern Pacific Denver Locomotive Shop	680 Seminole Rd Denver Co 80204	Denver	4011	Railroads, Line - Haul Operating	39.7264	-105.0058
Lakewood Brick & Tile Co	1325 Jay St Lakewood Co 80214	Jefferson	3251	Brick And Structural Clay Tile	39.6933	-105.0644
Univ Of Co Health Sciences Ctr	4200 E 9th Ave Denver Co 802203706	Denver	8221	Colleges And Universities, Nec	39.7308	-104.9378
Amoco Usa Operations Geisick No1	Ne Sec 32 T32s R66w Las Animas Cnty Co 00000	Las Anima	1311	Crude Petroleum & Natural Gas	37.6811	-104.1958
Amoco Usa Operations Horn Springs No3	Ne Sec 33 T32s R66w Las Animas Cnty Co 00000	Las Anima	1311	Crude Petroleum & Natural Gas	37.6811	-104.1958
Amoco Usa Operation Horn Springs No5	Se Sec 33 T32s R66w Las Animas Cnty Co 00000	Las Anima	1311	Crude Petroleum & Natural Gas	37.6811	-104.1958
Amoco Usa Operations Horn Springs No4	Ne Sec 33 T32s R66w Las Animas Cnty Co 00000	Las Anima	1311	Crude Petroleum & Natural Gas	37.6811	-104.1958
Amoco Usa Operations Horn Springs No7	Ns Sec 33 T32s R66w Las Animas Cnty Co 00000	Las Anima	1311	Crude Petroleum & Natural Gas	37.6811	-104.1958
Amoco Production Co Wacker No 1	Sec 25 T32s R66w Las Animas Co 80000	Las Anima	1311	Crude Petroleum & Natural Gas	37.6811	-104.1958
Amoco Production Co Co Univeristy No 1	Sec 35 T32s R67w Las Animas Co 80000	Las Anima	1311	Crude Petroleum & Natural Gas	37.6811	-104.1958

Facility Name	Facility Mailing Address	County	SIC	Industry Type	Latitude (Degrees)	Longitude (Degrees)
Coors Brewing Co Valley Complex	12th St & Ford St Golden Co 80401	Jefferson	2082	Malt Beverages	39.7567	-105.2186
Ralston Purina Co Pet Food Plt	4555 York St Denver Co 802163907	Denver	2047	Dog Cat And Other Pet Food	39.7794	-104.9594
Schafer Commercial Seating Inc	4101 E 48th Ave Denver Co 802163206	Denver	2599	Furniture And Fixtures, Nec	39.7842	-104.9406
Colorado State Univ	Csu Facility Svcs Fort Collins Co 80521	Larimer	4961	Steam Supply	40.5753	-105.0792
Fort Carson Usarmy	Fort Carson Colrado Springs S Of Co 80913	El Paso	9711	National Security	38.7578	-104.7975
U.S. Department Of Energy - Rfets	93 & Cactus Avenue Golden Co 80402	Jefferson	3341	Secondary Nonferrous Metals	39.8914	-105.2011
Cu Boulder Buffalo Power Cogen	18th St & Colorado Ave Boulder Co 803090053	Boulder	4961	Steam Supply	40.0083	-105.2689
Amoco Production Co	Nw Sec 36 T32s R66w Las Animas Cnty Co 00000	Las Anima	1311	Crude Petroleum & Natural Gas	37.2192	-104.735
Anheuser Busch Inc	Co Road 52 & I-25 Fort Collins Co 805220000	Larimer	2082	Malt Beverages	40.635	-105.0314
Colorado Springs Utilities Water Resourc	Hanna Ranch Utilities Complex Colorado Springs Co	El Paso	1442	Construction Sand And Gravel	38.6367	-104.6967
Waste Mgmt Of Co Inc	4200 E County Line Rd Littleton Co 80126	Douglas	4953	Refuse Systems	39.5664	-104.9569
Gates Rubber Co	990 S Broadway Denver Co 802094071	Denver	3069	Fabricated Rubber Products, Nec	39.6986	-104.9872
Western Mobile Southern Inc	1300 W Fillmore St Colorado Springs Co 80907	El Paso	2951	Paving Mixtures And Blocks	38.8764	-104.8431
Amoco Production Co	Sec 21 T32s R66w Las Animas Co 80000	Las Anima	1311	Crude Petroleum & Natural Gas	37.2408	-104.7778
Public Service Co Denver Steam Plant	19th St At Delgany St Denver Co 80202	Denver	4911	Electric Services	39.7558	-104.9986
Diamond Shamrock Refining & Mktg Co	7810 Drennan Rd Colorado Springs Co 80910	El Paso	5171	Petroleum Bulk Stations & Terminals	38.7811	-104.64
Coors Ceramics Co Electronics Div	17750 W 32nd Ave Golden Co 80401	Jefferson	3264	Porcelain Electrical Supplies	39.765	-105.2008
Summit Pressed Brick Mfg Plt	13th & Erie Pueblo Co 81002	Pueblo	3251	Brick And Structural Clay Tile	38.2789	-104.5997
Ripe Touch Greenhouses Llc	2 Mi Ssw Calhan Colo El Paso Cnty Co 00000	El Paso	4931	Elec & Other Services Combined	38.83	-104.52
Amoco Production Company	Ne Sec 36 T32s R67w Las Animas Cnty Co 80000	Las Anima	1311	Crude Petroleum & Natural Gas	37.3181	-104.6728
Denver City & County Maintenance Yard	5440 Roslyn St Denver Co 802166003	Denver	9199	General Government, Nec	39.7947	-104.9022
Phillips Pipe Line Co Calhan Sta	Calhan Station El Paso Co 00000	El Paso	1311	Crude Petroleum & Natural Gas	38.83	-104.52
Co Mental Inst At Pueblo	1600 W 24th St Pueblo Co 81003	Pueblo	8063	Psychiatric Hospitals	38.2908	-104.6272
Rocky Mountain Bottle Co	10619 W 50th Ave Wheat Ridge Co 80033	Jefferson	3221	Glass Containers	39.7861	-105.1158
Public Service Co Louisville Site	Sec 17 T1s R69w Louisville Co 80027	Boulder	1311	Crude Petroleum & Natural Gas	39.9644	-105.1356
Browning Ferris Ind. Foothills Landfill	8900 Hwy 93 Sec27/28 T2s R70w Golden Co 80419	Jefferson	4953	Refuse Systems	39.8722	-105.2406
Stroud Oil Properties Inc	9100 County Rd 31.9 Weston 1 Mi Sw Of Co 80000	Las Anima	4922	Natural Gas Transmission	37.1272	-104.8564
Coors Ceramics Company Structural Div	600 9th St Golden Co 80401	Jefferson	3264	Porcelain Electrical Supplies	39.7597	-105.2214
Climax Molybdenum Company Henderson Mir	Sec 30 T3s R76w Empire_9 Mi W Of Co 80438	Clear Cree	1061	Ferroalloy Ores Exc Vanadium	39.7064	-105.8458
Holnam Inc	4629 N Overland Trl Laporte Co 80535	Larimer	3241	Cement, Hydraulic	40.6528	-105.1408
Don Kehn Const Inc	3617 E Rd 36 Fort Collins Co 80525	Larimer	2951	Paving Mixtures And Blocks	40.5089	-105.0094
Realite Lightweight Aggregates	11728 Hwy 93 Boulder Co 80303	Jefferson	1459	Clay And Related Minerals Nec	39.9058	-105.2317
Southwestern Portland Cement	5134 Ute Hwy Lyons Co 80540	Boulder	3241	Cement, Hydraulic	40.2089	-105.2289
Robinson Brick Co	1845 W Dartmouth Ave Denver Co 801101308	Denver	3251	Brick And Structural Clay Tile	39.6606	-104.9661
Evergreen Operation Corp	Sec 22 T33s R65w Las Animas Co 00000	Las Anima	1311	Crude Petroleum & Natural Gas	37.4052	-104.1145
Loveland Gas Processing Co Ltd	2707 S County Rd 11 Loveland Co 80537	Larimer	1311	Crude Petroleum & Natural Gas	40.3639	-105.0394
Koch Hydrocarbon Co Third Creek Plt	104th Ave & Gun Club Rd Brighton Co 80601	Denver	1311	Crude Petroleum & Natural Gas	39.8847	-104.6972
Trigen - Colorado Energy Corporation	12th & Ford Golden Co 80401	Jefferson	4961	Steam Supply	39.7567	-105.2186
Holnam Inc Portland Plt	3500 Hwy 120 Florence Co 81226	Fremont	3241	Cement, Hydraulic	38.3875	-105.0172
Cf & I Steel L P	2100 S. Freeway Pueblo Co 81004	Pueblo	3312	Blast Furnaces And Steel Mills	38.2372	-104.6125

* US EPA - AIRData NET Facility Emissions Report
* Friday, 17-May-2002 at 4:22:12 PM (USA Eastern time zone)
* Colorado NET Air Pollution Point Sources - Carbon Monoxide (1999)
* Pollutant Emissions In Tons Per Year
* Field 1: Pollutant Emissions
* Field 2: Percent of Total Emissions
* Field 3: Facility Name
* Field 4: Facility Mailing Address
* Field 5: State
* Field 6: County
* Field 7: Year
* Field 8: Industry Type (SIC)
* Field 9: Facility ID
* Field 10: Latitude (Degrees)
* Field 11: Longitude (Degrees)
* Field 12: Region

Appendix E. Research Notes

Infusion for forests in works

Up to $9 million allocated for projects in the Rockies

Bob Berwyn
Special to The Denver Post
Friday, September 12, 2003 - Top officials in the U.S. Forest Service's Rocky Mountain region in late August allocated up to $9 million for several large-scale forest health projects - and Front Range communities at risk from wildfire stand to benefit, said regional forester Rick Cables.

"We've got some 22 million acres at risk across the region," Cables said. "They're not all in the same condition. They're not all critical watersheds or proximate to homes. We did a rapid assessment to identify areas at the highest risk."

Along with the Arapaho and Roosevelt, Pike and San Isabel national forests, which already were slated to receive funds under the Front Range Fuels Partnership, a team that includes forest supervisors and other experts agreed to concentrate efforts on several additional national forests: Black Hills National Forest in South Dakota, the San Juan, Grand Mesa, Uncompahgre and Gunnison national forests in Colorado, and Shoshone National Forest in Wyoming, Cables said.

Some of the money will come from funds authorized under the National Fire Plan, but the regional office will also shift funds from one area to another, and even between budget categories. Some of the forest health money will come out of the roads and recreation budgets, explained Terri Gates, director of communications and legislative affairs at the regional office.

"We had to make some hard budget decisions," Cables said. "We hope that, through this process, we'll get more funding for the region. If not, we'll do what we can in our own budget."

Hal Gibbs, ecosystem group leader for the Arapaho and Roosevelt National Forest, said his forest will receive $3.1 million, with $2.2 million budgeted for the Pike and San Isabel National Forest. Another $500,000 will help agency researchers study forest health issues, including the effectiveness of various treatment strategies. Gibbs said the Colorado Forest Service also garnered $500,000, available for grants to private property owners. The rest of the $9 million will go to the other forests.

Instead of a piecemeal approach to forest health, planners want to tackle larger chunks, working collaboratively with state and local officials, as well as private property owners. Gibbs explained. Focused funding will allow for a higher number of treatments, including thinning and prescribed burns. For example, the Arapaho and Roosevelt treated 1,500 acres in 2002. This year, the acreage doubled to 3,000 acres, and in 2004 the forest plans work across 7,000 acres.

"One area we're looking at is around Crystal Lakes, northwest of Fort Collins," Gibbs said, describing it as a "classic wildland-urban interface," with residences and summer homes scattered throughout areas of forest at risk for wildfires.

Projects are also planned in the Boulder Creek drainage, near the area where the 1989 Black Tiger fire destroyed 44 homes and burned 2,100 acres in less than seven hours, even though firefighters responded within 20 minutes. Gibbs characterized the area as a patchwork of federal, state and private lands, requiring cooperative planning.

"If we didn't get this (extra funding), we'd still be stuck at treating 1,500 acres per year," Gibbs said.

The Pike and San Isabel National Forest is looking at 20 to 25 projects totaling about 22,000 to 23,000 acres, said fire management officer Ted Moore, explaining that the Front Range fuels partnership is the foundation for the latest regional funding initiative. Moore singled out forests around Harris Park and areas west of Evergreen as high-priority areas.

Environmental groups acknowledge the need to thin areas where past fire suppression has created tinderbox conditions in ponderosa pine forests. But the Forest Service still needs to address key issues, said Rocky Smith, who analyzes agency plans for the watchdog group Colorado Wild!.

At issue, he said, is the disposal of the slash, or debris, that results from thinning. The agency must also consider potential impacts from subsequent activities, including increased motorized use in thinned areas, Smith said, explaining that conservation groups are trying to make sure their concerns are considered early in the process.

And commercial logging components of forest health projects are a constant thorn, as environmental groups point out there is plenty of science showing that removing older, large-diameter trees can make the forests more susceptible to fire.

Cables acknowledged those concerns but said the fuels must be controlled. Land managers can't control other factors in the fire equation, like drought or topography, but they can address the fuels buildup, he said.

"I think we can do it in a way that's ecologically beneficial," Cables concluded.

Appendix F. Results of Interviews with Local Officials

County	Contact Name	Number	Land-owner type	Department	Total acres managed by county	Acres at high risk of wildfire	Total acres in need of treatment	Acres mechanically thinned (2002)	Acres mechanically thinned per year past 5 years average	Expected acres to be thinned per year (next 5 years)	Cost of mechanical thinning ($/acre)	Number of slash piles burned (piles/year)	Chipped and left on site (acres/year)	Other uses - firewood (cords)
Boulder	Randy Coombs	(303) 441-3964	County	Parks and Open Space	18,000	ND	11,000	100	100	100	1,000	1,600	0	25
Chaffee	Paul R. Janzen	(719) 539-2579	CSFS	Salida District, Colorado State Forest Service	13,000	27,000	36,117	160	150	170	1,000	20	25	234
Clear Creek	Holland Smith	(303) 679-2460	County	Planner II, Clear Creak County Lands Department Golden District (Russ), Colorad, State Forest Service csfsgo@lamar.colostate.edu	5,755	3,465	2,000	-	None - Terrain limits access	-	NA	0		
Custer	John/Jeff/Janis	(719) 275-6865	ND	(JD) County Assessors' Office (719) 783-2218 or the CO State Forest Service (719) 275-6865 (John/Jeff/Janis) -- Canyon City District										
Douglas	Jackie Sanderson		ND	Mike Batim, Franktown District										
El Paso	Pat Farrell	(719) 520-6375	ND	Left a message 11am 4Aug --Supervior, El Paso County Parks----Woodland District-Colorado State Forest Service (Chuck Costecka)										
Fremont	Janis/Jeff/John	(719) 275-6865	ND	Canyon City District Colorado State Forest Service (Janis) -- Canyon City District										
Gilpin	Tom Gagnon	(303) 582-5831 op#4	ND	Boulder District Colorado State Forest Service & Alan Owen (303) 823-5774										
Grand	Mike Harvey	(970)887-3121	State	Mike Harvey, District Forester, Colorado State Forest Service, PO Box 69, Granby, CO 80446	50,000	15,000	10,000	400	200	300	1,200	1,000	2,000	2,500
Huerfano		(719) 743-3588	State	CK Morey, Colorado State Forest Service, La Veta District	76,000	67,000	71,000	90	130	100	1,190	100	5	44
Jefferson	Rocco Snart	(303) 271-4902	ND	Jefferson County, Wildlife Mitigation Coordinator-Golden District (Russ Lewis) csfsgo@lamar.colostate.edu & Alan Galamoor (303) 279-9757										
Lake	Paul R. Janzen	(719) 539-2579	State	Salida District, Colorado State Forest Service	1,300	18,000	24,994	15	15	20	1,500	0	0	27
Larimer	Tony Simons	(970) 498-7718	County	Kerry Traynor, (970) 679-4577, TraynorKL@co.larimer.co.us Larimer County Open Space, Referred me to Tony Simons - Wildfire Safety email may be Tsimons@larimer.org----Craig Jones referred me to Mike Babler, District Forester, (970) 491-8660 mbabler@colostate.edu										
Las Animas	CK Morey		Not sure	CK, Morey Colorado State Forest Service La Veta District	551,000	300,000	466,000	1,250	833	2,500	1,240	1,500	130	120
Park	Craig Barraclough	(790) 836-4288	ND	Craig Barraclough, Director of GIS, Park County, PO Box 571, 1246 County Road #16, Fairplay, CO 80440-0571 & Woodland District (Chuck)					None - count doesn't manage forest land					
Pueblo	Steve Douglas	(719) 583-6201	County	Director of Emergency Management	100									
Saguache		(719) 587-0915	ND	Alamosa District										
Teller	Kevin Tanski	(719) 687-5242	County	Division of Parks	1,320		700	-	-	-	1,000			

Appendix G. Biomass Technology Vendors

(Data in this Appendix were compiled by McNeil Technologies Inc. Originally published in, *Biomass Resource and Technology Assessment for the Four Corners Region,* April 2003. Prepared for Four Corners Sustainable Forests Partnership under contract to New Mexico Energy Minerals & Natural Resources Department, Forestry Division)

Company Name	Contact Person	Phone	Email	Web address	Address	Technology
Biomass furnaces, boilers for commercial and industrial and residential heat, steam and power applications						
Passat Energi A/S		+45 86 65 21 00	passat@passat.dk	www.passat.dk	Vestergade 36 Ørum Sønderlyng, DK - 8830 Tjele	biomass boilers
Taylor Waterstoves		(800) 545-2293	tmi@intrstar.com	www.taylormfg.com		Furnaces - hot water heat
York-Shipley Global	Ron Garee	(800) 366-5334	rgaree@aesystech.com	www.aesystech.com	693 North Hills Road York PA 17402-2212	Boiler, burner, and accessory manufacturer
Biomass Combustion Systems		(508) 393-4932	info@biomasscombustion.com	www.biomasscombustion.com	16 Merriam Road - Princeton, MA 01541	Furnace & boiler systems: 150-1200 HP
Chiptec	Robert Bender	(800) 244-4146	chiptec@together.net	www.chiptec.com	48 Helen Ave. South Burlington VT 05403	Boilers, gasifiers, cogeneration, and waste reduction systems
Converta Kiln Inc.	Pat Plass/ Vernon Plass	(800) 949-5456 (901) 358-4596			P.O. Box 341362 Bartlett TN 38184-1362	Gasifier/boiler systems for steam and heat production
Babcock & Wilcox	John Doyle	(303) 761-3388	jbdoyle@babcock.com	www.babcock.com	3535 S. Platte River Drive Unit G-3 Sheridan CO 80110	Boilers and power systems
Barlow Group, Inc.	Gregg Tomberlin	(970) 226-8557	office@barlowgroup.com	www.barlowgroup.com	2000 Vermont, Ste 200 Fort Collins CO 80525	Boilers and power systems Engineering, startup & commissioning, O&M, Engineering/Procurement/Construction
Black & Veatch	Mr. Warren Davis	(925) 246-8014		www2.bv.com/energy/eec/biomass.htm	2300 Clayton Rd Ste 1200, Concord CA 94520	Boiler & power systems: Engineering/Procurement/Construction
Detroit Stoker Company		(800) STOKER4		www.detroitstoker.com	1510 East First Street P.O. Box 732 Monroe, MI 48161	Biomass boilers
Foster-Wheeler Inc.	Bill Dillon	(908) 713-2500 x2310	bill_dillon@fwc.com	www.fwc.com	Perryville Corporate Park P.O. Box 4000 Clinton, New Jersey 08809-4000	Boiler/power plant engineering, design, construction & finance, O&M
Siemens Westinghouse				www.siemenswestinghouse.com		Boilers & power systems
Nebraska Boiler		(402) 434-2006	sales@neboiler.com	www.neboiler.com	6940 Cornhusker Highway Lincoln, NE 68507	Steam generators and high temperature hot water generators
Messersmith Manufacturing	Gailyn Messersmith	(906) 466-9010	sales@burnchips.com	www.burnchips.com	2612 F Road, Bark River, MI, 49807	Biomass boiler and furnace conversions
Cleaver-Brooks			info@cleaver-brooks.com	www.cleaver-brooks.com		High and low pressure boilers
Industrial Biomass Inc.		(815) 562-6400	industrialbiomass@industrialbiomass.com	www.industrialbiomass.com	8800 South Route 251 Rochelle, IL 61068	Grinders, fuel bins, furnaces, boilers, and auxiliary equipment
Energy Products of Idaho	Kent M. Pope	(208) 765-1611	epi@energyproducts.com	www.energyproducts.com	4006 Industrial Ave Coeur d'Alene, Idaho USA 83815-8928	Fluidized bed boilers, gasifiers, combustion; materials handling
Hurst Boiler & Welding Company, Inc.		877-99HURST 229-346-3545	info@hurstboiler.com	www.hurstboiler.com	Highway 319 N., Coolidge, GA 31738	Boilers
Skinner Engines	John Feuell	(814) 459-0570	skinnereng@aol.com		337 West 12th Street, PO Box 1149, Erie, Pennsylvania 16403	Turbines

Company Name	Contact Person	Phone	Email	Web address	Address	Technology
Biomass furnaces, boilers for commercial and industrial and residential heat, steam and power applications						
Industrial Boiler & Mechanical Co., Inc.		(888) 853-4714	randy@industrialboiler.com	www.industrialboiler.com	3325 N. Hawthorne Street P. O. Box 5100 Chattanooga TN 37406	Boiler installation, repair, and maintenance
Solagen Inc.	Francis Sharron	(503) 366-4210	fsharron@solageninc.com	www.solageninc.com	33993 Lawrence Road Deer Island , Oregon, 97054	Burners, stokers, rotary dryers
Biomass Energy Concepts	Dave Gamble	(205) 910-5141	dgamble@becllcusa.com	www.becllcusa.com	2240 Rocky Ridge Rd. Birmingham, AL 35216	Turnkey biomass cogeneration systems
Southern Engineering & Equipment Co.		(800) 536-2525		www.seecousa.com	2240 Rocky Ridge Rd. Birmingham, Alabama 35216, 800.536.2525	steam turbine-generator systems for cogeneration applications
NESTCO	Bob Rivard	(508) 885-7950	bob@nestco1.com	www.nestco1.com	64 Main Street, P.O. Box 916, Spencer, MA 01562, USA	steam turbine-generator systems for cogeneration applications
Biomass Energy Services & Technology		+61 2 4340 4911	best@biomass.com.au	www.users.bigpond.net.au/biomass	56 Gindurra Rd SOMERSBY NSW 2250 AUSTRALIA	Fluidized bed boilers, gasifiers, combustion; materials handling
Small modular biomass systems - Precommercial technology (design or prototype stage)						
External Power (partners SunPower, Wood Mizer)	Elaine Mather	(740) 594-2221	mather@sunpower.com	www.sunpower.com	182 Mill Street Athens, OH 45701	Combustion / Stirling engine
STM Corporation	Dr. Benjamin Stiph	(834) 995-1755			275 Metty Drive, Ann Arbor, MI 48103	Gasification / Stirling engine
FlexEnergy	Edan Prabhu	(949) 380-4899	edanprabhu@cox.net	www.flexenergy.com	22922 Tiagua, Mission Viejo, CA 92692	FlexMicroturbine (downdraft gasifier/microturbine)
Community Power Corporation	Robb Walt	(303) 933-3135	rwalt@gocpc.com	www.gocpc.com	8420 S. Continental Divide Road Suite #100 Littleton, CO 80127	Downdraft gasifier, dry gas cleanup, ICE/generator
Energy & Environmental Research Center	Darren Schmidt	(701) 777-5000	mjones@eerc.und.nodak.edu	www.eerc.und.nodak.edu	University of North Dakota PO Box 9018 Grand Forks, ND USA 58202-9018	Combustion / heat exchange / steam turbine
Agrilectric Research Inc.	Karl T. Alexander	(225) 922-4662	kalexander@powellgroup.com	www.agrilectric.com	P.O. Box 788 Baton Rouge, LA, USA 70821	Combustion / steam turbine
Carbona Corporation	Jim Patel	(770) 956-0601			4501 Circle 75 Parkway Suite E 5300 Atlanta, GA 30339	Updraft gasification, boiler, steam turbine

Company Name	Contact Person	Phone	Email	Web address	Address	Technology
Biomass Gasification						
BG Technologies USA		(410) 740-3025	bgsystems@bgtllc.com	www.bgtechnologies.net	10480 Little Patuxent Parkway, Suite 400, Columbia, MD 21044	Gasification system packages
Beierle Energy Associates		509-786-1298			P.O. Box 903 Prosser, WA, USA 99350	Portable and stationary gasifiers
Waste to Energy Ltd	Mike Ling	01787 373007	mike.ling@waste-to-energy.co.uk	www.wastetoenergy.co.uk	Eyston, Borley Green, Sudbury, Suffolk, C010 7AH	Gasifier modules
XYLOWATT SA		++41 +21 948.86.61	info@xylowatt.ch	www.xylowatt.ch	Rte de Vevey 1618 Châtel-St-Denis, Switzerland	Gasifier modules (turnkey systems)
Thermogenics, Inc.		(505) 761-5633	thermogenics@thermogenics.com	www.thermogenics.com	Tom Taylor, President/ Thermogenics, Inc., 7100-F Second Street NW, Albuquerque, New Mexico 87107 USA	Gasification system packages
Wellons Incorporated	Ken Kinsley	(503) 625 6131	Sales@WellonsUSA.com	wellonsusa.com/	PO Box 1030, Sherwood, Oregon 97140-1030	Engineers and manufactures a range of equipment to burn wood-waste fuels for energy production for the forest products industry; also offers complete engineering and project management
Cratech	Joe Craig	(806) 327 5220	cratech@onramp.net			Pressurized fluidized bed 1.2MWe gasifier for cotton trash etc.
Biofuels						
Power Energy Fuels, Inc.	Gene Jackson	(303) 205-1991	gene@powerenergy.com	www.powerenergy.com	6595 W. 14th Ave. Suite 203 Lakewood, Colorado 80214-1998	Converts biomass gasifier output to Ecalene(TM)
Renewable Oils Int'l	Phil Badger	(256) 740-5634	pbadger@renewableoil.com	www.renewableoil.com	3115 Northington Ct. Florence, AL 35360	Converts biomass to fuel oils and chemicals
Ensyn Group	Robert Graham	(617) 266-7600		www.ensyngroup.com	20 Park Plaza, Suite 434 Boston, MA 02116	RTP™ Biomass to bio-oils conversion process
Dynamotive	James Acheson	(323) 460-4900	james.acheson@DynaMotive.com	www.dynamotive.com	134 North Van Ness Avenue Los Angeles, CA 90004	Biomass to bio-oils conversion process
Pellet Fuels Institute	Rob Davis	(928) 537-1647	rdavis@forestenergy.com	www.pelletheat.org	1601 North Kent Street, Suite 1001 Arlington, VA 22209	Pellet fuel manufacturing technology, markets - industry association

Biobased product manufacturing technology

Technology	Description	Feed Stock type	Biomass used (GT/year) (a)	Moisture Content, %	Capital Costs, $ (a)	Production costs ($/unit)	Production capacity (note units)	Uses
Charcoal (1)	Gasification process/ pressure and high temperature (8)	Wood, nut shells, pits, agricultural residues, organic (8)	Not available	Any (8)	$350k-1M est.	$70-100/ton charcoal (8)	100-400 lb biomass/hr (prototype) (8)(a)	barbecue charcoal, chemical reactants, activated carbon, soil amendment, power plant fuel
Pressed logs (2)	Logs for fireplace, barbeque or boiler	Compressed sawdust & other residues (4)	2,200 (5)	4-8 % (6)	$57000 (7)	Not available	Not available	Heat, recreation, cooking
Densified wood (17)(a)	Pressed logs, briquettes and 1-1 1/2" dia pellets are all forms of densified wood products	Compressed wood chips and sawdust	4,000 per machine	<10%	$350000 (17)	~$0.17/lb	2000 ton/yr	Heat, recreation, cooking
Wood pellets (3)	Used in pellet stoves	Sawdust & ground wood chips	30,000 - 500,000	6% (b)	$370k - $2M (19)	$87 - $94/ton (19)	680,000 ton/yr (18)	Heat
Small-diameter sawmills	Fixed or portable; process trees of 3" dia. and larger	Logs up to 36" dia.	Variable		$5700 - $2M (16)	Not available	up to 13 million board feet/yr (15)	Dimensional lumber
Cellulose ethanol fuel (10), (11)	Ethanol derived from lignocellulose	Wood, agricultural residues, paper sludge	720,000 - 1,400,000	dry	$136M - $215M	$1.50/gal (12)	25 - 50 Million gal/yr	Transportation, power plant
Bio-oils (1/2 Btu content of fuel oil)	Substitute for fuel oil for heating, stationary engines	Woody or grassy materials	2,000 to 36,500	10%	$2M to $3.5M	$0.095-0.135/gal (13)	12,000 gal/day for 100 GT/day plant	as substitute or additive to petroleum, kerosene and diesel fuels
Fiber reinforced thermoplastics	wastewood/paper-derived fillers (WPFs) (12.5% by weight) are used to reinforce thermoplastics	Wastewood and paper-derived fillers	1,100 minimum	6 - 8%	$1.07M est. (14)	$0.50/lb (14)	4400 ton/yr	replace conventional filled thermoplastics

Notes

(a) values are for a single plant
(b) Moisture content here refers to the final product
(1) Solid Fuels and Feedstocks Program managed by DOE's National Energy Technology Laboratory (NETL), Assumes a facility that produces 700,000 tons of biomass per year.
(2) Assume average insulation, a domestic occupancy profile (heating for 10 hrs/day, 7 d/wk, 30 wk/yr = 2100 hours per year) and burning beech logs at 25% moisture content. If, for instance,the
(3) Source: Wisconsin Department of Natural Resources. On-line at: http://www.dnr.state.wi.us/org/aw/air/ed/pellets.htm
(4) Heatlogs can be made from a variety of biomass materials, such as: Sawdust, Sugar Cane residues, Rice Husks, Palm Oil residues, Sunflower husks, Coconut husks, etc.
(5) Shimada Heatlog press can process 500 kg/hour (500 kg/hr*40 hr/wk * 50 wk/yr = 1,000,000 kg/yr [2.2x10^6 lb/yr])
(6) Shimada Heatlog press requires moisture content of 4%-8%
(7) $57,000 Shimada Heatlog press; price does not include other required components
(8) University of Hawai'i Process for Charcoal Production
(9) Annual world charcoal use is est. 26-100 M metric tonnes. At 50% yield, this would require 52-200 M metric tonnes/year biomass.
(10) Andrew McAloon, Frank Taylor, Winnie Yee, Kelly Ibsen and Robert Wooley, *Determining the Cost of Producing Ethanol from Corn Starch and Lignocellulosic Feedstocks*, October 2000,
(11) Costs are 1999 dollars
(12) Includes depreciation of capital
(13) C. Daey Ouwens, A. Faaijb, *A comparison of the production costs, and the market introduction of Fischer-Tropsch oil and ethanol*, 5th International Biomass Conference Abstract
(14) (1996 Dollars) Brent English, Craig M. Ciemons, Nicole Stark, James P. Schneider, *Wastewood-Derived Fillers for Plastics*, The Fourth International Conference on Woodfiber-Plastic Composites
4 million kg/yr wastepaper-fibre reinforced thermoplastic compounding facility
(15) HewSaw R200, Veisto Group
(16) $1.45 M USD, HewSaw R200, with scanning conveyor, scanning frame, high-speed log conveyor, controls, etc. (e-mail from Ken Hall 2002-04-26) / $5731 USD,
(17) West Virginia University, Publication No. 838, *Wood Densification*, Sept. 1988
(18) Total North American Production (Pellet Fuels Institute, 2002)
(19) Prices are 1993 dollars. Scott Haase, Denise Rue, Jack Whittier, *Wood Pellet Manufacturing in Colorado: An Opportunity Analysis*,

Appendix H. Economic Analysis and Assumptions

McNeil personnel utilized a proprietary spreadsheet pro forma income statement model to estimate the cost of electricity from a biomass power plant. The model is used to determine the levelized cost of electricity from the perspective of a non-utility or merchant plant perspective. The model contains the following elements.

General Plant Performance

This information relates to the size of the facility, the fuel input requirements and the generation output.

> *Biomass Resource Requirements*: The total amount of wood necessary to operate the facility given its installed capacity, energy conversion efficiency, and energy content for the biomass fuel. This is a calculated value.
>
> *Station Capacity*: The installed capacity in kilowatts of the facility.
>
> *Net Plant Heat Rate*: The efficiency of the power conversion system.
>
> *Internal Power Use (parasitic)*: This value is a percent of total energy and capacity of the system not available for sale to the grid.
>
> *Annual Capacity Factor*: Over the course of an entire year, the percentage number defines the level of output of the facility when in operation.
>
> *Annual Availability Factor*: The amount of time in a year that the facility is in operation and is not shut down for repairs and outages.
>
> *Plant Factor*: The product of the annual capacity factor and the annual availability factor.
>
> *Annual Energy Production*: Calculated by multiplying the station capacity and the plant factor and multiplying that product by the number of hours in a year (8760 hours).

Installed Capital Costs

Depending upon data availability, McNeil uses price quotes, technical knowledge of equipment and installation costs based upon prior projects, or reported data from the literature to determine the total installed capital costs. Unless specifically identified, capital costs include items associated with engineering, procurement and construction (EPC). EPC costs typically cover 60-90 percent of total costs and are exclusive of land acquisition, spare parts, and miscellaneous charges.

Financial Data

Income Tax Rate: If the facility is a profitable venture, federal and state income taxes for the owner will apply.

Electricity Inflation/Escalation Rate: The annual rate of escalation for electricity purchases. This value is assumed to be considerably lower than the general inflation rate because of competitive pressures in the utility industry.

General Inflation/Escalation Rate: Inflation is accounted for as a real increase in certain expenses over the lifetime of the project.

Interest rate on debt: An assumed value dependent upon current economic conditions.

Equity ratio: The ratio between debt and equity. Typically projects utilize about 20 percent equity.

Down Payment on Loan: A percentage value of the total installed capital costs.

Depreciation Method: MACRS depreciation is utilized in the model for the principal capital cost components.

Book Life: The book lifetime is expected to be twenty years. The project lifetime is 25 years.

Annual Plant Insurance: Annual property insurance will be required on the capital cost of the facility.

Annual Generation and Production Assumptions

Variable Operations and Maintenance: O&M costs that vary with plant output that include consumables (i.e., chemicals, lubricants), start up fuel, and outside services for miscellaneous repairs.

Fixed Operations and Maintenance: For the purposes of this model, fixed costs are limited to personnel costs that are scaled to meet the facility capacity.

Fuel Costs: Fuel costs are based on the amount and type of available wood waste for use in the system. It is assumed that the least expensive resource will be used first and in its entirety and then the next least expensive resource will be consumed until the demand can be met.

Pro Forma Income Statement

Income: Includes all revenues, both real and apparent, received by the project. Revenues may fall into the following categories.

Electricity Sales: Revenue created by selling electricity.

Capacity Payment: Revenue associated with capacity sales.

Steam Valuation: Revenue attributable to steam sales if the project includes a combined heat and power option.

Energy Production Incentive: Revenue derived from payments to the project by US DOE at $0.015/kWh and adjusted annually for inflation. This value is not used in the present analysis because the credit is not available at this time.

Expenses: This category details the annual costs associated with operating and financing the facility. This includes debt servicing, resource fuel acquisition, payroll, and general O&M such as chemicals, repairs and maintenance, and consumable/other. By acquiring new equipment, the debt servicing of the loan amount is the most significant annual expense for the project.

Operating Income: Income less expenses.

Pretax Income: Operating Income less debt service.

Income Taxes and Tax Credits: Federal tax rate on the plant's income.

Net Cash Flow: Sum of net income and depreciation.

Net Present Value (NPV): The sum of the present values from each year minus the initial investment of the project.

Levelized Cost: The cost of building and operating the facility over a 25-year lifespan on a per kilowatt-hour basis. The levelized cost is calculated by summing the total expenses, taxes, and depreciation for each year of the project and determining the net present value, then dividing by the total kWh produced during the 25-year period.

Year 2 Return on Investment: The ROI is the Net Present Value divided by the installed cost of the fixed assets**.**